SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT I, NOBUAKI KUBO, a citizen of Japan residing at Tokyo, Japan has invented certain new and useful improvements in

LIGHT SCANNING DEVICE, SCANNING LINE
ADJUSTING METHOD, SCANNING LINE ADJUSTING CONTROL
METHOD, IMAGE FORMING APPARATUS, AND IMAGE
FORMING METHOD

of which the following is a specification:-

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a light scanning device, and an image forming apparatus using the light scanning device.

2. Description of the Related Art

A light flux from a light source is deflected by light deflecting means such as a rotational polygon mirror. The deflected light flux is focused to a scanned surface by using a scanning imaging optical system including an $f\theta$ lens. In this manner, a light spot is formed on the scanned surface. A light scanning device that uses the light spot to scan the scanned surface is well known as a device related to an image forming apparatus such as an optical printer, an optical plotter, and a digital copier.

In the image forming apparatus using the light scanning device, an image writing process of writing an image by light scanning is adopted as one process in an image forming operation. Quality of an image formed by the imaging process is affected by quality of light scanning. The quality of light scanning depends on scanning characteristics of a main scanning direction and a sub scanning direction.

Speed uniformity of light scanning is one of the scanning characteristics of the main scanning direction.

For example, when the rotational polygon mirror is used as the light deflecting means, a light flux is deflected in a uniform angular speed manner. For this reason, in order to realize speed uniformity of light scanning, a scanning imaging optical system that includes $f\theta$ characteristics is used.

However, since there are other characteristics required for the light imaging optical system, it is difficult to completely realize the $f\theta$ characteristics. Accordingly, in actual light scanning, there are no cases where the light scanning is performed in a completely uniform angular speed, so that the speed uniformity as the scanning characteristics is different from ideal light scanning speed uniformity.

The scanning characteristics of the sub scanning direction include a scanning line curve and a scanning line inclination.

A scanning line is a trajectory of a light spot on the scanned surface, and an ideal scanning line is a straight line. The light scanning device is designed such that the scanning line becomes a

straight line. However, in reality, scanning line
curve is usually generated due to a machining error,
and an assembling error.

Further, in a case where an imaging mirror
is used in the scanning imaging optical system, and
the deflected light flux is made to have an angle in
terms of the sub scanning direction of the deflected
light flux between an incident direction and a
reflection direction of the deflected light flux to
the imaging mirror, in principle, the scanning line
curve is generated. Even when the scanning imaging
optical system is configured as a lens system, it is
impossible to avoid the scanning line curve in a
multi-beam scanning method in which scanning is
performed on the scanned surface by using a plurality
of light spots divided in the sub scanning direction.

The scanning line inclination is a
phenomenon in which the scanning line does not
appropriately cross the sub scanning direction at a
right angle. Since the scanning line inclination is
one kind of the scanning line curve, in the following
description, the term "scanning line curve" may
include the scanning line inclination.

When the light scanning speed is incomplete,
distortion in the main scanning direction is

generated in the formed image. The scanning line curve causes distortion in the sub scanning direction to be generated in the formed image.

In a case where an image is mono-color, that is, the image is formed by a single light scanning device, if the scanning line curve and incompleteness of the speed uniformity are suppressed to a certain degree, the formed image does not include distortion that a human eye can recognize. However, it is preferable that there is less distortion in the image.

Different from the mono-color image, in a conventional color copier and the like, each color component image of three colors of magenta, cyan, and yellow, or four colors of magenta, cyan, yellow, and black is formed, and these color component images are made to overlap each other in order to form a color image.

As a color image forming method, there is a tandem type image forming method in which respective color component images are formed on photoconductive bodies by using respective light scanning devices. In a case of such an image forming method, if scanning curve and inclination degrees in the respective light scanning devices are different from each other, even if the respective scanning line

curves in the light scanning devices are adjusted, an abnormal image called "color difference" is generated in the formed color image, so that color image quality is deteriorated.

5   The color difference phenomenon includes a phenomenon in which a color tone (hue) in the formed color image is different from a desired color tone.

       In order to prevent a problem of the above-mentioned color difference, Japanese Patent

10   Application Laid Open No. 2002-131674 discloses a scanning line curve adjustment structure in which both sides of a supporting unit for a long lens is provided between an optical axis of the long lens, and one side of the supporting unit is configured

15   such that the long lens can be moved in the sub scanning direction by an adjusting screw. In this structure, adjusting the screw causes the long lens to be rotated in a section plane orthogonal to a deflection direction to adjust the scanning line

20   curve.

       However, in Japanese Patent Application Laid Open No. 2002-131674, there is a possibility that the scanning line curve cannot be adjusted in an environment affecting a material of the lens used in

25   the imaging optical system. The reason of this is as

follows.

Recently, in order to improve scanning characteristics, a special surface of which representative is non-spherical surface was generally adopted in the imaging optical system of the light scanning device. It is relatively common to use the imaging system that enables such a special surface to be easily formed, and that is configured by a resin material of which cost is low.

The imaging optical system including the resin material can be easily affected by temperature and humidity change, resulting in change of optical characteristics. This change of the optical characteristics causes the scanning line curve degree and the speed uniformity to be also changed. For this reason, when successively forming color images of tens of pages, a temperature in an image forming apparatus is raised due to the successive operation. Accordingly, the optical characteristics of the imaging optical system are changed, and the curve of the scanning line written by the respective light scanning devices (optical writing devices), and the speed uniformity are gradually changed, in some cases, resulting in the color difference in which the color tone of the first formed image is entirely different

from the color tone of the last formed image.

A scanning imaging lens such as representative $f\theta$ lens in the scanning optical system is formed as a thin lens that is long in the main scanning direction such that unnecessary portion (that the deflected light flux does not enter) of the scanning imaging lens in the sub scanning direction is cut. In a case where a plurality of lenses constitute the scanning imaging system, as the disposed position of the lens is more away from the light deflecting means, the length of the lens in the main scanning direction becomes longer, so that the long lens having the length of ten-odd cm to 20 cm or more is required. Such a long lens is generally formed in resin molding by using a resin material, but when the temperature distribution in the lens becomes inhomogeneous, the lens is warped and arched in the sub scanning direction. This warping of the long lens causes the scanning line curve, and when the warping is large, the scanning line curve also becomes very large. Even when the configuration of Japanese Patent Application Laid Open No. 2002-131674 is used to perform initial adjustment, this phenomenon is generated. Furthermore, the configuration disclosed by Japanese Patent

Application Laid Open No. 2002-131674 does not take

into consideration the scanning line inclination that

also causes the color difference. In Japanese Patent

Application Laid Open No. 2002-131674, the position

5 of the lens in the optical axis direction is changed

by screw fastening degree, so that it is difficult to

maintain accuracy in the position of the lens.

Recently, accompanying higher speed color

image forming, four photoconductive drums (bodies)

10 are arranged in a direction of transporting paper,

and a plurality of optical systems corresponding to

these respective photoconductive drums form latent

images simultaneously on these photoconductive drums.

Then, developing units use developing agents of

15 different colors (for example, yellow, magenta, cyan,

and black) to turn these latent images into visible

images, and these visible images are successively

transferred on the same paper on top of one another

to obtain a color image. An image forming apparatus

20 (four drum tandem type) such as a digital copier and

a laser printer that form a color image has been put

into practical use.

In the four drum tandem type, a mono color

image and a color image can be output at the same

25 speed, so that the four drum tandem type is

advantageous for high speed printing. However, when the toner images developed on the photoconductive drums are transferred to the paper on top of one another, a color difference is generated. In the
5   case of the four drum tandem type, since a multi-color image is formed by successively transferring respective color toner images on top of one another, the generated scanning line position displacement is scattered among the respective colors, resulting in
10 the color difference.

In order to reduce the color difference, there are the following methods.

First, Japanese Patent Application Laid-Open No. 2001-133718 discloses a method in which the
15 position of the entirety of respective optical elements is adjusted relative to the photoconductive body so as to conform the respective scanning lines to each other. However, a mechanism for performing this adjustment becomes complicated, so that it is
20 difficult for this method to deal with optical characteristics change due to time lapse (for example, temperature change). Furthermore, in this method, it is difficult to correct the color difference with high accuracy during a printing operation or a used
25 state.

Secondly, Japanese Patent Application Laid-Open No. 2001-100127 discloses the method in which the scanning beam position is controlled in the sub scanning direction by using a galvanometer mirror.

5   However, the galvanometer mirror has too high sensitivity in controlling the scanning position in the sub scanning direction. Accordingly, this method is easily affected by outside vibration. In order to realize further improved beam spot diameter, higher

10   surface accuracy is required.

Third, Japanese Patent Application Laid-Open No. 10-239939 discloses the method in which in accordance with phase relation between a middle transfer reference signal and a line synchronization

15   signal, out of a plurality of laser beams, a laser beam for first writing an image on a photoconductive body is switched so that an image writing start position for each color in the sub scanning direction can be adjusted. However, also in this method, it is

20   impossible to achieve correcting accuracy of less than one line. For example, in a case of image writing of 600 dpi, a color difference (position displacement larger than 42 μm) is generated.

Further, when a tilt amount of the

25   reflection mirror is changed, an optical path length

up to the image holding body becomes different between a center part and end parts of the scanning line. This problem is called a magnification error in the main scanning direction.

5   The causes of the color difference, particularly, in the sub scanning direction in the tandem type image forming apparatus include: ① nonuniformity of speed on the photoconductive body in the circumferential direction (in the sub scanning

10   direction); ② nonuniformity on the middle transfer body in the circumferential direction (in the sub scanning direction); ③ a position error between the photoconductive bodies; ④ writing position displacement of a beam spot between scanning optical

15   systems; and ⑤ position displacement due to ① to ④ caused by environmental change or temperature change at the time of successive printing. In addition, when writing is performed on each photoconductive body by using multi beams, there is a possibility

20   that a position is displaced by an amount depending on the number of beams because the rotation of the polygon scanner is not synchronized with the speed on the photoconductive body. Furthermore, in some cases, the color difference in the sub scanning direction is

25   caused by change of the optical length due to an

error of the thickness of the middle transfer body.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a light scanning device that can effectively suppress deformation of an optical element (for example, a resin-made optical element) included in a scanning optical system (scanning imaging optical system), and that can correct a scanning line curve and speed nonuniformity, easily and accurately. The deformation of the optical element is caused by temperature change, for example.

It is another object of the present invention to provide a light scanning device that can effectively suppress the deformation of the optical element (for example, the resin-made optical element) included in the scanning imaging optical system, and that can accurately correct scanning line curve and inclination so that good quality of a color image having less color difference can be formed.

It is another object of the present invention to provide a scanning line correcting method, a scanning line correcting control method, and an image forming apparatus having the above light scanning device.

According to one aspect of the present invention, there is provided a light scanning device comprising:

light deflection means for deflecting a light beam emitted from a light source;

a scanning imaging optical system that forms a light spot on a scanned surface, using the light beam;

shape maintaining means for preventing or reducing deformation of a resin-made optical element included in the scanning imaging optical system;

scanning line curve correcting means for correcting a curve of a scanning line by using the shape maintaining means; and

scanning line inclination correcting means for correcting an inclination of the scanning line by using the shape maintaining means.

According to another aspect of the present invention, there is provided a light scanning device comprising:

an optical element that images, on an image holding body, a light beam emitted from a light source;

a holding member that holds the optical element;

scanning line curve correcting means for correcting the optical element in a sub scanning direction to correct a scanning line formed by the light beam in the sub scanning direction; and

5   scanning line inclination correcting means for entirely tilting the optical element to correct an inclination of the scanning line,

wherein at least one part of the scanning line curve correcting means, and at least one part of

10   the scanning line inclination correcting means are provided integrally with the holding member.

According to another aspect of the present invention, there is provided a method of correcting a curve and/or inclination of a scanning line of light

15   beam emitted from a light source, comprising the steps of:

correcting an optical element in a sub scanning direction to correct the curve of the scanning line, the optical element imaging the light

20   beam on an image holding body; and

entirely tilting the optical element to correct the inclination of the scanning line.

Other objects, features, and advantages of the present invention will become more apparent from

25   the following detailed description when read in

conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a basic configuration of a
5 light scanning device according to a first embodiment
of the present invention;

FIG. 2 shows one function of the light
scanning device of FIG. 1;

FIG. 3 shows another function of the light
10 scanning device of FIG. 1;

FIG. 4 shows another function of the light
scanning device of FIG. 1;

FIGS. 5A through 5D show examples of
configurations for detecting a position difference
15 and a color difference that are used in the light
scanning device of FIG. 1;

FIG. 6 shows a configuration of scanning
line curve correcting means and scanning line
inclination correcting means that are used in the
20 light scanning device of FIG. 1;

FIG. 7 is a plan view of the scanning line
curve correcting means and the scanning line
inclination correcting means of FIG. 6;

FIG. 8 is a cross sectional view taken in
25 the direction indicated by the arrow (8) of FIG. 7;

FIG. 9 shows a position displacement state of a light spot caused by the deformation of a long lens due to temperature change;

FIG. 10 shows a result obtained by correcting the position displacement shown in FIG. 9;

FIG. 11 shows a set configuration of the long lens;

FIG. 12 is a plan view of the set configuration shown in FIG. 11;

FIG. 13A is a front view taken from the direction indicated by the arrow (13) of FIG. 12, and FIG. 13B is a side view taken from the direction indicated by the arrow (B) of FIG. 13A;

FIG. 14 is a perspective view showing an optical system that includes the scanning line curve correcting means and the scanning line inclination correcting means in the light scanning device for a plurality of scanned surfaces;

FIG. 15 is a perspective view showing an outline of a light scanning device according to a second embodiment of the present invention that is mounted in an image forming apparatus;

FIG. 16 shows an important part of the light scanning device of FIG. 15;

FIG. 17 is a sectional front view of the

important part of FIG. 16;

FIG. 18 is a sectional side view of a held optical element provided in the light scanning device of FIG. 15;

5   FIG. 19 is a plan view showing an outline shape of the held optical element provided in the light scanning device of FIG. 15;

FIG. 20 is a sectional side view of the important part of the light scanning device shown in

10   FIG. 16;

FIG. 21 is a sectional side view showing a principle of a correcting operation performed by writing start position adjusting means according to the second embodiment of the present invention;

15   FIG. 22 is a front view showing the writing start position adjusting means of FIG. 21;

FIG. 23 shows arrangement of position displacement detection means according to the second embodiment of the present invention;

20   FIG. 24 is a correlation graph showing relation between a torque and a driving frequency of a stepping motor;

FIG. 25 is a correlation graph showing relation between a temperature in the light scanning

25   device and the number of printed pages;

FIG. 26 shows a principle of detecting a position by using a non-parallel photo diode sensor as beam spot position detection means;

FIG. 27A shows dot position displacement in the sub scanning direction caused by speed change on a medium transfer body, and FIG. 27B shows dot position displacement in the sub scanning direction after the beam spot position is corrected;

FIG. 28 shows another configuration example of the scanning line curve correcting means in the light scanning device according to the second embodiment;

FIG. 29 is a sectional front view of the light scanning device of FIG. 28;

FIG. 30 is an important part of the scanning line curve correcting means of FIG. 28;

FIG. 31 shows another configuration example of the scanning line inclination correcting means in the light scanning device according to the second embodiment of the present invention;

FIG. 32 shows another configuration example of the scanning line inclination correcting means in the light scanning device according to the second embodiment of the present invention;

FIG. 33 shows another configuration example

of the scanning line curve correcting means in the light scanning device according to the second embodiment of the present invention;

FIG. 34 shows an important part of the scanning line curve correcting means of FIG. 33;

FIG. 35A shows another important part of the scanning line curve correcting means in the light scanning device according to the second embodiment of the present invention, and FIG. 35B is a sectional front view of the important part of FIG. 35A;

FIG. 36 shows relation between the number of pressing means and an adjusted amount of the scanning line curve;

FIG. 37 shows comparison of a magnification error between a span band method and a MUSIC method;

FIG. 38A is a table showing magnification error change in the case of the span band method, and FIG. 38B is a table showing magnification error change in the case of the MUSIC method;

FIG. 39 shows comparison of beam spot diameter change in the main scanning direction after inclination correcting between the span band method and the MUSIC method;

FIG. 40 shows comparison of beam spot diameter change in the sub scanning direction after

inclination correcting between the span band method and the MUSIC method; and

FIG. 41 shows a configuration of an image forming apparatus to which the light scanning device of the first and second embodiments may be applied;

DETAILED DESCRIPTION OF THE PREFERED EMBODIMENTS

Embodiments of the present invention will be described with reference to the drawings.

First, an image forming apparatus to which a light scanning device is applied will be described.

FIG. 41 shows an image forming apparatus to which a light scanning device according to embodiments of the present invention is applied. The image forming apparatus shown in FIG. 41 may be a copier or a printer that can form a full color image. However, the image forming apparatus of FIG. 41 may be a facsimile machine that can perform image forming process same as that of the copier or the printer, based on an image forming signal. Furthermore, the image forming apparatus 1 may be a composite machine of any combination among a printer, a copier, and a facsimile machine. The image forming signal may be received from outside the image forming apparatus 1. The image forming apparatus includes not only an

apparatus for a full color image, but also an apparatus for a single color image.

The image forming apparatus 1 of FIG. 41 has a tandem structure in which a plurality of

5 photoconductive drums each of which can form an image corresponding to one of the decomposed colors (yellow, cyan, magenta, and black) are arranged side by side. Visible images formed on the respective photoconductive drums 1A, 2A, 3A, and 4A are

10 transferred to transfer paper S of a recording medium that is transported by a transfer belt 5 with the respective visible images being put on top of each other. The transfer belt 5 can move while facing the respective photoconductive drums. The recording

15 medium S may be standard paper such as paper for copying, an OHP sheet, heavy paper such as a card or postcard, an envelope, or any other sheet type recording medium

A configuration of the photoconductive drum

20 1A for an image forming process will be described. However, the other photoconductive drums 2A through 4A may have the same configuration as that of the photoconductive drum 1A, and the same reference symbols (alphabets) of components related to the

25 photoconductive drum 1A are used for components of

the photoconductive drums 1A through 4A. In order to perform the image forming process along the rotational direction indicated by the arrow, around the photoconductive drum 1A, there are arranged a

5 charging device using a configuration such as a corotron or scorotron (in Fig. 41, a configuration using a roller), a light scanning device 20 or 1020 using laser light from a light source (described later in detail), a developing device 1D, and a

10 cleaning device 1E.

In the image forming apparatus shown in FIG. 41, a document (image) reading unit 6 is provided above an image forming unit constituted by these devices 1A, 1B, and so on that perform the image

15 forming operation. In the document reading unit 6, a reading device 7 reads a document and the like placed on a document placing tray 6A, and image information read by the reading device 7 is output to an image processing control unit (not shown) to obtain writing

20 information for the light scanning device 20 or 1020. The charging device 1B is not limited to a contact type using a roller, and may be a corona discharge type using a discharge wire.

In this example, the developing devices are

25 arranged so as to provide toner in the order of

yellow color toner, cyan color toner, magenta color toner, black color toner, from the right side of Fig. 41.

5 The reading device 7 includes a light source 7A for scanning a document placed on the document placing tray 6A, a plurality of reflection mirrors 7C, and an imaging lens 7D. A plurality of reflection mirrors 7C, and the imaging lens 7D are provided for imaging light reflected from the document, on a CCD 10 7B. The CCDs 7B are provided for the decomposed colors, respectively. Image information based on light intensity of each of the decomposed colors is output from the CCDs 7B to the image processing control unit.

15 The transfer belt 5 is a member constituted by a dielectric such as a polyester film that is put on and partly around a plurality of rollers. A part of stretched and spreading part of the transfer belt 5 faces the respective photoconductive drums 1A 20 through 4A, and transfer devices 8A, 8B, 8C, and 8C are provided at the reverse sides of the transfer belt 5 at the side of the photoconductive drums 1A through 4D. A record medium S such as paper is sent to the transfer roller 5 from a paper supply cassette 25 9A of a paper supply device 10 via a resist roller 9.

The record medium S is absorbed to the transfer belt 5 by electrostatic absorption caused by corona discharge generated from the transfer device 8A. In this manner, the record medium is transported by the

5   transfer belt 5. A thickness of the transfer belt 5 is about 100 μm. The thickness of the transfer belt 5 has an error of $\pm$ 10 μm. As described later, when toner images of the respective colors overlap, there is a possibility that position displacement occurs,

10   but this position displacement is corrected by writing start position adjusting means 1140 described later.

Image transfer is performed on the record medium S, and is then sent to a dividing device 11,

15   and a charge removing device 12 is provided across the part of the stretching and spreading part of the transfer belt 5. Further, In FIG. 41, the reference number 13 designates a cleaning device that removes toner remaining on the transfer belt 5.

20   The transfer devices 8A through 8D generate positive corona discharge so that images held by photoconductive drums 1A through 4A can be attached to the record medium S by electrostatic absorption.

The dividing device 11 generates negative

25   corona discharge to an upper surface of the record

medium S so that an electrical charge of the record
medium S can be neutralized, removing an
electrostatic absorption state. At this time, a
curvature of the transfer belt 5 is used for dividing

5   the electrical charge, and toner dust caused by
removing discharge can be prevented. From both sides
of the transfer belt 5, the charge removing device 12
generates negative AC corona discharge that is
reverse electrical polarity of the charging

10   characteristics of the transfer devices 8A through 8D
so that an electrical charge accumulated on the
transfer belt 5 is neutralized and electrically
initialized.

          As for the photoconductive drums 1A through

15   4A, the charging devices 1B through 4B uniformly
charge surfaces of the photoconductive drums 1A
through 4A. The writing devices 1C through 4C form
electrostatic latent images on the photoconductive
drums, based on the respective decomposed color image

20   information read by the reading device 7 of the
document reading unit 6. Each of the developing
devices 1D through 4D supply color toner
corresponding to complementary color relation of the
decomposed color to turn the electrostatic latent

25   image into a visible image. Thereafter, each of the

transfer devices 8A through 8D transfers the visible image to the record medium S held and transported by the transfer belt 5.

The record medium to which the images of the
5   respective decomposes color held by the photoconductive drums 1A through 4A are transferred divided from the transfer belt 5 by using a curvature of the transfer belt 5 after the charge of the record medium S is removed by the charge removing device 11.
10   After that, the record medium S is moved to a fixing device 14 where toner on the record medium S is fixed thereto.   Then, the record medium S is discharged on a discharge tray outside a main body of the image forming apparatus 1.

15   FIG. 1 shows a basic structure of a light scanning device 20 for the above-described plural photoconductive drums according to a first embodiment of the present invention.

In FIG. 1, two light beams 21A' and 21B'
20   emitted from a light source device 21 including two semiconductor lasers 21A and 21B are focused on a deflection reflection surface of a polygon mirror 23 in terms of a sub scanning direction by a cylindrical lens 22. The polygon mirror 23 functions as a
25   deflector.   Then, using the focused light beams 21A'

and 21B', the polygon mirror has a function of

forming long line images in a main scanning direction.

A second part 24 of an imaging optical system

including an fθ lens scans a scanned surface (the

5   photoconductive drum 1A, for example) by forming

light spots thereon. It should be noted that in FIG.

1, the light source device 21 is constituted by the

semiconductor lasers and coupling lenses, but the

present invention is not limited to this

10   configuration.

When the light scanning device is used as an

optical writing device of an image output device, a

light beam is modulated for output image data, but an

electrical signal (synchronization signal) for a

15   modulation start timing is obtained by entering of

the light beam to a synchronization detection plate

25.

As shown in FIG. 2, two light beams 21A' and

21B' cross each other at an angle θ (when seen from a

20   sectional direction orthogonal to the main scanning

direction) in the vicinity of the deflection

reflection surface of the polygon mirror 23. In this

manner, a difference in optical characteristics

(imaging plane curve, magnification error) between

25   the two light beams can be suppressed.

As shown in FIG. 3, it is required that the
two light spots BS1 and BS2 should maintain a
predetermined interval (beam pitch PZ) in the sub
scanning direction in accordance with scanning
5 density. As shown in FIG. 4, an angle ϕ made by the
two light beams 21A' and 21B' in terms of the sub
scanning direction may be set so as to obtain the
predetermined beam pitch.

The light scanning device shown in FIG. 1
10 includes a liquid crystal deflection element 26
between the polygon mirror as the deflector and the
second part of 24 of the imaging optical system.

The liquid crystal deflection element 26
having an effective area corresponding to the main
15 scanning area may be provided so as to be divided in
the main scanning direction or the sub scanning
direction. The liquid crystal deflection element 26
for the main scanning direction, and the liquid
crystal deflection element 26 for the sub scanning
20 direction may be provided so as to overlap each other
in the optical axis direction. Thus, by
appropriately arranging the liquid crystal deflection
element 26, the light beam can be deflected to adjust
the light spot position on the scanned surface. This
25 light beam deflection is performed by driving and

controlling (modulating) the liquid crystal
deflection element 26, using an electrical signal
from control means (not shown). In this case, a
control method for the liquid crystal deflection
5   element 26 may be feedback or open loop.

The scanning line is curved or inclined by
an accuracy problem of the optical element, a curve
of a generatrix, and an arrangement error at the time
of assembling in an optical housing. According to
10 the first embodiment of the present invention, based
on a detection result of means for detecting a curve
and inclination on the scanned surface 1A (i.e., on
the photoconductive drum 1A), or based on a detection
result of means for detecting a color difference of a
15 color patch formed on the transfer belt 5, an
electrical signal is used to perform the driving and
the controlling (modulating) of the liquid crystal
deflection element 26. In this manner, the curve and
inclination of the scanning line can be adjusted.
20 This operation will be described later with reference
to FIGS. 5A through 5D.

Next, an amount of the scanning line
inclination will be described. The contribution to
the amount of the scanning line curve and inclination
25 includes a curve amount caused by the light scanning

device itself, and an amount caused by other factors other than the light scanning device. These accumulated contribution leads to a curve or inclination of an image, and in the worst case, an

5   inclination of hundreds of microns can be generated.

According to the first embodiment, the light scanning device 20 can adjust the scanning line curve and/or inclination caused by not only the light scanning device itself 20, but also other factors.

10   In other words, scanning line curve correcting means for correcting the scanning line curve, the scanning line inclination correcting means for correcting the scanning line inclination, (described later), and shape correcting means are

15   provided so that the curve and inclination of hundreds of microns can be adjusted to the curve and inclination of tens of microns or less. Furthermore, the liquid crystal deflection element 26 enables an amount of the scanning line curve and inclination to

20   be reduced to tens of microns. Moreover, optical characteristics change caused by temperature and humidity change is adjusted to further improve accuracy of the scanning line.

When adjusting the scanning line curve to

25   tens of microns by the liquid crystal deflection

element 26, a large deflection angle is required.

However, if the deflection angle is made large, a

response speed of the liquid crystal deflection

element 26 is reduced. For this reason, it is

5   difficult to perform adjustment at a high accuracy by

using the liquid crystal deflection element 26.

The above-mentioned scanning line position

detection means for detecting the scanning line curve

or detecting a color difference may has any one of

10   configurations shown in FIGS. 5A through 5D.

In the configurations of FIGS. 5A and 5B,

the scanning line position detection means is

provided inside or near the light scanning device.

In FIG. 5A, the liquid crystal deflection element 26

15   is tilted so that an area sensor AS can receive the

light reflected from the liquid crystal deflection

element 26 to detect a displacement of the scanning

position. In FIG. 5B, a half mirror HM is separately

provided so that the area sensor AS can detect the

20   scanning position.

In the configurations of FIGS. 5C and 5D,

the area sensor AS detects a reflection state of

light that is generated from a light source P and is

reflected from the photoconductive drum 1A to detect

25   a position difference and/or a color difference of a

toner image T on the photoconductive drum 1A.
According to the configurations of FIGS. 5C and 5D,
this reflection state is detected at a stage of an
almost finally formed image, so that detection

5   accuracy can be high.

The light scanning device having the above-
described configuration further includes the scanning
line curve correcting means for correcting the
scanning line curve, and the scanning line

10   inclination correcting means for correcting the
scanning line inclination. In the following,
configurations of these means will be described.

FIG. 6 shows the scanning line curve
correcting means for correcting the scanning line

15   curve, and the scanning line inclination correcting
means for correcting the scanning line inclination,
and shape maintaining means for maintaining a shape
of a long lens. The scanning line curve correcting
means for correcting the scanning line curve, and the

20   scanning line inclination correcting means for
correcting the scanning line inclination, and the
shape maintaining means are integrated with the
resin-made long lens (hereinbelow, these means are
together referred to as scanning line

25   curve/inclination adjusting/correcting means 100).

The long lens is used in the second part 24 of the
imaging system (imaging optical system).

In the first embodiment, a curve of the
scanning line is resolved by adjusting a tilt
5 (indicated by β tilt of FIG. 6) of the long lens 101
in the direction orthogonal to the optical axis. An
inclination of the scanning line is resolved by
adjusting a tilt (indicated by γ of FIG. 6) of the
long lens 101 around the optical axis. The
10 configuration for this adjustment will be described
as follows.

In FIG. 6, the scanning line
curve/inclination adjusting/correcting means 100
includes the shape maintaining means 102 for
15 maintaining a shape of the long lens 101.

The shape maintaining means 102 corrects
deformation of the long lens 101 such as warping
caused by temperature change. For this correction of
the deformation, the shape maintaining means 102
20 includes a lower side metal plate member 102A that
can put the long lens 101 thereon and determine a
position of the long lens 101, an upper side metal
plate member 102B that can press an upper surface of
the long lens 101, and gap maintaining members 102C
25 that are provided at both sides of a longitudinal

direction of the long lens, respectively. The metal
plate members 102A and 102C are respectively attached
to upper and lower sides of the gap maintaining
members,

5   Both sides of a longitudinal direction of
each of the lower side metal plate 102A and the upper
side metal plate 102B are fixed to the gap
maintaining members 102C, respectively so that a gap
between the metal plates 102A and 102B can be

10   determined. This gap length may be approximately
equal to or smaller than a height of the long lens in
the sub scanning direction. In this manner, both
sides of the long lens 101 in the sub scanning
direction is sandwiched between the upper side metal

15   plate 102B and the lower side metal plate 102A so
that generation of deformation or warping of the long
lens 101 can be suppressed, and a curve of a
generatrix of the long lens 101 can be corrected and
held.

20   Position alignment protruding parts 102A1
for aligning the position of the long lens 101 are
provided on a center part in the longitudinal
direction on the lower side metal plate 102A. The
position alignment protruding parts 102A1 sandwich

25   (engage) an engagement part formed on the long lens

101 to align the position of the long lens in the
longitudinal direction (main scanning direction).

In FIG. 6, by fixing screws 103, both ends
of the upper side metal plate 102B in the

5   longitudinal direction thereof are fixed to a support
base unit 104 provided at a part of the optical
housing.   Near both ends of the upper side metal
plate member 102B, thin parts 102B1 are formed,
respectively, with the thin parts 102B1 being

10   separated to the longitudinal center of the metal
plate member 102 from both ends thereof.   The thin
part 102B1 is formed by cutting off edge surface part
orthogonal to the longitudinal direction.   The this
part 102B1 is twisted in the direction indicated by β

15   of FIG. 6 more easily than other parts of the upper
side metal plate member 102A.

A γ adjusting screw 105 that can adjust a
tilt (indicated by γ of FIG. 6) of the long lens 101
around the optical axis penetrates through the upper

20   side metal plate member 102B at the position
separated from each thin part 102B1 to the
longitudinal center of the metal plate member 102B.
Specifically, each adjusting screw 105 is provided at
the position that is the center of the direction

25   orthogonal to the longitudinal direction of the metal

plate member 102A. Furthermore, β adjusting screws 106 that can adjust a tilt (indicated by β of FIG. 6) of the long lens 106 in the direction orthogonal to the optical axis penetrate through the upper side

5 metal plate member 102B. As shown in FIG. 6, the β adjusting screws 106 are respectively positioned at both sides of each γ screw 105 in the direction orthogonal to the longitudinal direction of the metal plate member 102B.

10   Specifically, the β adjusting screws 105 and the γ adjusting screws 106 penetrate through screw holes formed on the upper side metal plate member 102B. Front edges of these adjusting screws 105 and 106 contact against the support base unit 104.

15 With this configuration, by adjusting a rotational direction of the these screws 105 and 106, and rotated amounts of these screws 105 and 106, it is possible to move or rotate the upper side metal plate member 102B in the β direction and/or the γ

20 direction in FIG. 6. In this manner, a curve and/or inclination of the scanning line can be adjusted and corrected, and the moved amount of the upper side metal plate 102B is a correction amount for the tilt adjustment.

25   As described above, the upper side metal

plate member 102B is moved in the β direction and the
γ direction by adjusting the adjusting screws 105 and
106. At this time, the deformation of the upper side
metal plate member 102B can reach a plastic

5   deformation area, depending on the adjusting amount.
However, an adjusted state of the upper side metal
member 102B can be maintained by the rigidity of the
metal plate member 102B, and the friction engagement
between the metal plate member 102B and the adjusting

10   screws 105 and 106, so that the durability of the
metal plate member 102B against vibration can be
secured.

In addition to the adjusting screws 105 and
106, attachment screws 107 for fixing the upper side

15   metal plate member 102B to the gap maintaining
members 102C are provided on the upper side metal
plate member 102B, as shown in FIG. 7.

The gap maintaining members 102C to which
the upper side metal plate member 102B and the lower

20   side metal plate member 102A are fixed may be made of
a metal material or a resin material, but are formed
such that linear expansivity of the gap maintaining
members 102C made approximately same as that of the
long lens 101. In this manner, even when an

25   environmental temperature changes, a uniform

compression stress is generated in the long lens 101 and the gap maintaining member 102C so that the affected change of the optical characteristics of the long lens 101 can be minimized. In other words, even

5 when the environmental temperature changes, a uniform compression stress can be generated in the long lens and between the upper and lower side metal members 102B and 102A that sandwiches and holds the long lens 101 because the same linear expansivity exists in the

10 long lens 101 and between the upper and lower side metal plate members 102B and 102A. Accordingly, it is possible to prevent the change of the optical characteristics of the long lens 101 due to nonuniformity of the compression stress.

15   In the first embodiment, the inventor performed an experiment by using the scanning line curve/inclination adjustment/correcting means due to deformation of the long lens 101 caused by temperature change. A result of this experiment is

20 shown in FIGS. 9 and 10.

        FIG. 9 shows a result of measuring deformed amounts in time series at three points of the resin-made long lens 101 in a condition where the long lens 101 was placed on a reference board in a constant

25 temperature bath, and a temperature of the long lens

101 is changed from 25°C to 45°C. In FIG. 9, "H"
designates an image height that is a distance from a
reference position (e.g., corresponding to the center
of the long lens 101) in the main scanning direction.

5   In this experiment, warm air was forced to strike a
surface of the long lens 101 such that temperature
difference between a bottom side and an upper side of
the long lens 101 was generated with the bottom side
of the long lens 101 contacting with the reference

10   board. When the temperature was raised, the long
lens was warped upwards, and when a some amount of
time elapsed, the temperature in the long lens became
uniform, and the long lens restored the original
shape.

15   In a case where the long lens 101 is mounted
in the image forming apparatus, heat from the polygon
scanner, and heat by fixing operation are generated,
a curve and/or inclination of the scanning line is
generated, and in a case of the tandem type, a color

20   difference is generated.

          FIG. 10 shows a result of measuring deformed
amounts in time series at the three points of the
resin-made long lens 101 in the same condition of FIG.
9, but in the case of FIG. 10, the scanning line

25   curve/inclination adjusting/correcting means was used.

As understood from FIG. 10, deformation suppressing effect is sufficient.

FIGS. 11 through 13 show the long lens 101 installed to the shape maintaining means 102. As shown in FIG. 11, both ends of the long lens 101 in the longitudinal direction are attached to step parts as an optical axis direction striking parts formed on the gap maintaining parts 102C, respectively. The long lens 101 is fixed to the step parts 102C1 by pressing springs 108. In FIGS. 11 through 13, the upper side metal plate member 102B is not shown.

The lower side metal plate member 102A and the upper side metal plate member 102B that sandwich the long lens 101 are fixed to the gap maintaining members 102C by attaching screws 107 so as to be integrated to the gap maintaining members 102C. Accordingly, the long lens 101 fixed to the gap maintaining members 102C can be moved integrally with the shape maintaining means 102 at the time of moving the shape maintaining means 102 in the β direction and the γ direction.

According to the above-described configuration in the first embodiment, by operating the γ adjusting screws 105 and the β adjusting screws 106 of the shape maintaining means that

functions as shape correcting means, initial

adjustment for the scanning line curve is performed

with respect to the long lens integrated with the gap

maintaining members 102C of the shape maintaining

5   means 102.

       Furthermore, in accordance with a detection

result from the position detection means or the color

difference detection means shown in FIG. 5, driving

control of the liquid crystal deflection element 26

10   is performed so that the scanning line curve due to

the time lapse shape change including temperature

change characteristics of the long lens can be

adjusted (corrected) without generating an adverse

effect in the liquid crystal deflection element 26.

15   Accordingly, at the time of initial adjustment, the

scanning line curve/inclination can be corrected by

the shape maintaining means 102, and the β adjusting

screws 106 and the γ adjusting screws 105 of the

shape maintaining means 102. Furthermore, the

20   scanning line curve and inclination due to time lapse

such as the temperature change can be corrected by

the liquid crystal deflection element 26.

       The above-described scanning line

curve/inclination adjusting/correcting means for

25   adjusting/correcting the scanning line curve and/or

inclination may be applied to the light scanning

device 20 as the tandem optical system shown in FIG.

1. A configuration of the scanning line

curve/inclination adjusting/correcting means for

5   application to the tandem optical system of FIG. 1 is

shown in FIG. 14.

As shown in FIG. 14, in the light scanning

device 20 as the tandem optical system, the basic

structure shown in FIG. 1 for a plurality of

10   photoconductive drums 1A, 2A, 3A and 4A on which the

respective color images are formed is used.

Furthermore, in FIG. 14, the integral type scanning

line curve/inclination adjusting/correcting means 100

for adjusting/correcting the scanning line curve

15   and/or inclination are applied to the long lenses 101

and 101'. Moreover, the liquid crystal deflection

elements 26 and 26' are provided between the polygon

mirrors PM and PM' as the deflectors and the first $f\theta$

lenses L1 as the scanning lenses, respectively. In

20   FIG. 14, the reference numbers 27 and 27' designate a

first scanning semiconductor laser, and a second

semiconductor laser, respectively; the reference

numbers 28 and 28' designate first scanning

reflection mirrors, respectively, and the reference

25   numbers 29 and 29' designate second scanning

reflection mirrors. Further, in FIG. 14, the optical

members after the liquid crystal deflection elements

26 and 26' in the optical path constitute the second

part 24 of the imaging system of FIG. 1 for the

5   respective photoconductive drums.

By using the above-described light scanning

device as the tandem optical system, it is possible

to suppress the shape change of the long lenses 101

and 101' due to environmental temperature change, and

10   to correct the scanning line curve and/or inclination

due to the deformation of the long lenses 101 and

101'. Furthermore, by using the liquid crystal

deflection elements 26 and 26', it is possible to

further appropriately adjust a light spot position in

15   a state where an amount of the scanning line curve

and/or inclination has been reduced by the scanning

line curve/inclination adjusting/correcting means for

adjusting/correcting the scanning line curve and/or

inclination.

20   According to the first embodiment, initial

adjustment can be performed by using the scanning

line curve/inclination adjusting/correcting means so

as to correct the scanning line curve and the

scanning line inclination. Furthermore, even when

25   environmental change such as temperature raise in the

light scanning device occurs (optical characteristics change caused by time lapse occurs), the scanning line curve and inclination can be corrected by correcting the deformation such as warping of an

5   imaging element (optical element), for example. Accordingly, it is possible to maintain good optical characteristics about the image displacement and the color difference) regardless of time lapse.

Further, according to the first embodiment,

10   by electrically controlling the liquid crystal deflection element, the scanning line curve and inclination caused by the environmental change can be corrected with high accuracy by feedback or open loop. When an adjustment amount larger than tens of microns

15   is required, the posture control of the optical element such as the long lens is performed, so that reasonable control can be performed without giving an excessive load to the liquid crystal element.

In addition, according to the first

20   embodiment, the relative position between the shape maintaining means and the long lens can be determined such that the shape maintaining means and the long lens are integrated with each other. The scanning line curve and inclination can be controlled together,

25   and the configuration of this is simple. Moreover,

in this configuration, an adjustment operation can be focused on one optical element, so that the component cost and the assembling cost can be reduced.

Further, according to the first embodiment, only by providing a thin part, the correcting of the scanning line curve and the correcting of the scanning line inclination can be performed independently of each other, with high accuracy. Furthermore, this configuration using the thin part is strong against vibration, so that it is possible to stably obtain an image that does not have an image displacement and a color difference.

Furthermore, according to the first embodiment, by making the linear expansivity of the long lens same as that of the supporting body that supports the long lens, it is possible to minimize the change of the compressing stress at the supporting body caused by the environmental temperature change. In this manner, the scanning line curve and inclination can be corrected. Therefore, it is possible to suppress change of the beam spot diameter and the magnification at the side of the long lens when the compressing stress is changed.

When the light scanning device is applied to

the tandem type multi-color image forming apparatus using the electrophotographic process, it is possible to correct the scanning line curve and inclination of each photoconductive body. Accordingly, it is

5   possible to improve image density, reduction of consuming power, vibration noise reduction, and generated heat reduction, resulting in reduction of environmental burden.

Next, a second embodiment of the present

10   invention will be described.

FIG. 15 shows a light scanning device 1020 that is a tandem type writing optical system. The light scanning device 1020 uses a scanning lens, but may use either of the scanning lens and a scanning

15   mirror. For simplicity, only two stations are shown in FIG. 15. However, four stations may be provided symmetrically with respect to polygon mirrors 1026 and 1027 as deflectors. The image forming apparatus adopts the four stations. The image forming

20   apparatus 1 can form a color image. In a case of forming a color image, the light scanning device 1020 is used for forming the color image.

The light scanning device 1020 includes two LD units 1021 and 1022 as light sources. The light

25   scanning device 1020 images (focuses) laser beams

emitted from the respective LD units 1021 and 1022 on
respective photoconductive bodies 1034 and 1038 that
are the photoconductive drums as image holding bodies.
For this operation, the light scanning device 1020

5   includes optical element groups 1051 and 1052
corresponding to the LD units 1021 and 1022, and the
photoconductive drums 1034 and 1038, respectively.
In this configuration, the light scanning device 1020
is configured to correspond to the photoconductive

10   bodies 1034 and 1038. Each of the photoconductive
bodies 1034 and 1038 may correspond to any one of the
above-described photoconductive drums 1A through 4A.

The LD units 1021 and 1022 are provided at
different heights in a sub scanning direction that is

15   approximately vertical direction. The light beam
from the upper side LD unit 1021 passes though a
writing start position adjusting means 1140, and
reflected by a midway reflection mirror 1023 to the
same direction in which the light beam from the lower

20   side LD unit 1022 runs. On the other hand, the light
beam from the lower side LD unit 1022 passes through
writing start position adjusting means 141, and then
passes through the reflection mirror 1023.
Thereafter, the light beams from the LD units 1021

25   and 1022 pass through cylindrical lenses 1024 and

1025 to be focused as a line shape in the vicinity of reflection surfaces of the polygon mirrors 1026 and 1027 that are separated from each other by a predetermined distance in the upward and downward

5   directions.

Each of the LD units 1021 and 1022 includes at least a semiconductor laser and a collimating lens. Each of the writing start position adjusting means 1140 and 1141 includes a wedge-shaped prism 1101 as

10   light refraction members shown in FIGS. 21 and 22. When the respective light beams from the LD units 1021 and 1022 pass through the writing start position adjusting means 1140 and 1141, the respective light beams penetrate through the writing start position

15   adjusting means 1040 and 1041, respectively. The polygon mirrors 1026 and 1027 may be connected to polygon motors (not shown) to be rotated.

Shapes of the light beams deflected by the polygon mirrors 1026 and 1027 are adjusted by the

20   first scanning lenses 1028 and 1029 that may be integrally formed or put on one another. Then, second scanning lenses 1030 and 1035 having f θ characteristics adjust the shapes of the light beams to be a predetermined beam spot diameter. In this

25   manner, the formed light spots scan surfaces of the

photoconductive bodies 1034 and 1038. After the first scanning lenses 1028 and 1029, the respective light beams run along different optical paths to be guided to the photoconductive bodies 1034 and 1038,

5   respectively.

The upper side light beam that penetrates through the first scanning lens 1028 is reflected by a reflection mirror 1031 by a right angle to an upward direction, and is again reflected by a

10   reflection mirror 1032 by a right angle so that the upper side light beam enters the second scanning lens 1030 that is a long plastic lens. Then, the upper side light beam is reflected by a reflection mirror 33 to a downward direction B so that the upper side

15   light beam can scan the photoconductive body 1034 in the main scanning direction A.

Meanwhile, the lower side light beam that penetrates through the first scanning lens 29 does not enter the reflection mirror 32, but enters the

20   second scanning lens 1035 that is a long plastic lens. Thereafter, the lower side light beams is reflected by two reflection mirrors 1036 and 1037 to scan the photoconductive body 1038 in the main scanning direction A that is separated from the

25   photoconductive body 1034 by a predetermined pitch.

In FIG. 15, the arrow C designates a direction of an optical axis of the second scanning lenses 1030 and 1035.

As shown in FIG. 23, a reflection mirror 1110 is provided directly above each of the photoconductive bodies 1A through 4A. Both end parts of the reflection mirror 1110 corresponding to parts outside an effective image region of each of photoconductive bodies 1A and 4A reflects the light beam. On the other hand, the light beam penetrates through a part of the reflection mirror 1110 corresponding to the effective image region of each of the photoconductive bodies 1A through 4A. The light beams reflected by the reflection mirror 1110 enter beam spot position detection means 1300a and 1300b, respectively, having a function as position displacement detection means. The beam spot position detection means 1300a is provided for detecting a writing start position, and the beam spot position detection means 1300b is provided for detecting writing end position.

The optical element group 1051 includes a plurality of optical elements, that is, the prism 1101, the reflection mirror 1023, cylindrical lens, the polygon mirror 1026, the first scanning lens 1028,

the reflection mirrors 1031 and 1032, the second

scanning lens 1030, the reflection mirror 1033, and

the reflection mirror 1110. Meanwhile, the optical

element group 1052 includes a plurality of optical

5   elements, that is, the prism 1101, the cylindrical

lens 1025, the polygon mirror 1027, the first

scanning lens 1029, the second scanning lens 1035,

the reflection mirrors 1036 and 1037, and the

reflection mirror 1110.

10   The light scanning device 1020 includes a

holding member 1061 that holds the second scanning

lens 1030 of the optical element system 1051, a

holding member 1062 that holds the second scanning

lens 1035 of the optical element system 1052. The

15   holding members 1061 and 1062 have the approximately

same structure, and the second scanning lens 1030

held by the holding member 1061, and the second

scanning lens 1035 held by the holding member 1062

have the approximately same structure. Accordingly,

20   in the following, the holding member 1061 and the

second scanning lens 1030 will be described as a

representative.

          As shown in FIG. 16, the light scanning

device 1020 includes scanning line curve correcting

25   means for correcting a curve of the scanning line on

the photoconductive body 1034 by correcting the

second scanning lens 1030 in the sub scanning

direction. The light scanning device 1020 further

includes scanning line inclination correcting means

5   for correcting an inclination of the scanning line on

the photoconductive body 1034 by inclining the entire

second scanning lens 1030.

As described above, for decreasing cost,

plastic is adopted for making resin element for the

10   optical system. In the case of the tandem type

writing system, the number of optical components is

large, so that employing plastic decreases const

greatly. Also in the second embodiment, the above-

mentioned optical elements are made of plastic.

15   However, warping of the long plastic optical

element is easily warped in the direction B

orthogonal to the longitudinal direction thereof (the

main scanning direction) due to a molding condition

and a remaining stress. An amount of the warping

20   reaches tens of microns, and the warped amount and

warped direction are scattered due to a mold

difference, so that it was very difficult to perform

alignment between the respective stations for the

scanning line curve and inclination. In the second

25   embodiment, in order to resolve such a problem, the

scanning line curve correcting means 1071 and the scanning line inclination correcting means 1072 are provided.

A part of members constituting the scanning
5 line curve correcting means and a part of the members constituting the scanning line inclination correcting means 1072 are integrated with the holding member 1061. Further, the scanning line curve correcting means 1071 and the scanning line inclination
10 correcting means 1072 are also provided at the second scanning lens 1035. Similarly, a part of members constituting the scanning line curve correcting means and a part of the members constituting the scanning line inclination correcting means 1072 are integrated
15 with the holding member 1062.

The holding member 1061 includes a supporting member 1063 that is long in the main scanning direction A, and supports the second scanning lens 1030 from the sub scanning direction.
20 The holding member 1061 further includes a sandwiching support member 1064 that sandwiches and supports the second scanning lens 1030 in cooperation with the supporting member 1063. The supporting member 1063 contacts against second scanning lens
25 1030, and includes a reference surface 1065 as a

position reference for the second scanning lens 1030 in the holding member 1061.

Each of the supporting member 1063 and the sandwiching support member 1064 is made of a metal plate and bent so as to have a U shape in a section thereof and have strength. A plane surface of each of the supporting member 1063 and the sandwiching support member 1064 contacts against the second scanning lens 1030. In the holding member 1063, the plane that contacts against the second scanning lens 1030 constitutes the reference surface 1065. A part of the second scanning lens 1030 is sandwiched between pins 1082 protruding from and provided on the reference surface 1065 so that the second scanning lens 1030 is fixed to the supporting member 1063 at the reference surface 1065.

A rectangular pillar 1066 that has a height approximately equal to thickness of the second scanning lens 1030 is provided at each of both end parts of the second scanning lens 1030 in the longitudinal direction thereof (i.e., the directions A). The rectangular pillars 1066 are provided for maintaining a gap between the supporting member 1063 and the sandwiching support member 1064. In a state where the second scanning lens 1030 is sandwiched

between the supporting member 1063 and the
sandwiching support member 1064, the rectangular
pillars 1066 are fixed to the supporting member 1063
and the sandwiching support member 1064, respectively,
5 by screws 1067. The rectangular pillars 1066, the
supporting member 1063, and the sandwiching support
member 1064 constitute the holding member 1061. In
FIG. 16, as for the screws 1067, only the screws 1067
for fixing between the sandwiching support member
10 1064 and the rectangular pillars 1066 are shown.

Members constituting the scanning line curve
correcting means 1071 are integrated with the
sandwiching support member 1064. The scanning line
curve correcting means 1071 includes a plurality of
15 scanning line curve correcting mechanisms 1081
arranged in the main scanning direction A. As shown
in FIGS. 16 and 17, each scanning line curve
correcting mechanism 1081 includes a pressing member
1073, and a pressing operation member 74 that presses
20 the pressing member 1073 against the second scanning
lens 1030. Each scanning line curve correcting
mechanism 1081 further includes a U-shaped bracket
1075 that is fixed on an upper surface of the
sandwiching support member 1064 by spot welding, and
25 supports the pressing operation member 1074.

Each pressing member 1063 presses the second
scanning lens 1030 from the opposite side to a
surface of the second scanning lens 1030 that
contacts against the supporting member 1063. A guide

5   hole 1076 is formed on one of both standing parts of
the bracket 1075, and a tap of which opening size is
larger than that of the guide hole 1076 is formed on
the other of the both standing parts of the bracket
1075. The pressing operation member 1074 includes a

10   large diameter part 1078, a small diameter part 1079,
and a tapered part 1080 that connects the large
diameter part 1078 to the small diameter part 1079.
A screw thread is formed on the large diameter part
1078 so that the pressing operation is formed as a

15   screw.

The small diameter part 1079 of the pressing
operation part 1074 penetrates through the guide hole
1076, and the large diameter part 1078 of the
pressing operation part 1074 penetrates through the

20   tap 1077 to engage the tap 1077. In this manner, the
pressing operation member 1074 can be supported by
the bracket such that the pressing operation member
1074 can move in an approximately axial direction A
thereof. Thus, the pressing operation member 1074 is

25   integrated with the sandwiching support member 1064

via the bracket 1075. Accordingly, the pressing
operation member 1074 that is a part of the scanning
line curve correcting mechanism 1081, i.e., the
scanning line curve correcting means 1071 is

5   integrated with the sandwiching support member, i.e.,
the holding member 1061.

The pressing member 1073 has a cylindrical
shape, and an axial direction of the pressing member
1073 is parallel to an optical axis direction of the

10   second scanning lens 1030. For the shape of the
pressing member 1073, a cut part 1041 is formed on
the bracket 1075, and a hole 1042 is formed on the
sandwiching pressing member 1064. The pressing
member is inserted in the cut part 1041 and the hole

15   1042 to directly contact with the second scanning
lens 1030. Alternatively, the pressing member 1073
may indirectly contact with the second scanning lens
1030 via an interposing plate.

The tapered part of the pressing operation

20   member 1074 contacts against the pressing member 1073,
and the pressing operation member is rotated by a
driver and the like so that the pressing operation
member 1074 is moved in the axial direction thereof
approximately orthogonal to the axial direction of

25   the pressing member 1073. In this manner, a position

where the pressing operation member 1074 presses the
pressing member in the direction B is changed.
Accordingly, at a position where the pressing member
1073 contacts against the second scanning lens 1030,

5   a position of the second scanning lens 1030 is
changed. Therefore, at the scanning line curve
correcting mechanism 1081, the pressing operation
member 1074 is rotated so that the scanning line
curve correcting means 1071 can correct, on the

10 photoconductive body 1034, the curve of the scanning
line formed by the light beam that passes through the
second scanning lens 1030.

        The curve of the scanning line on the
photoconductive body 1034 is generated by accumulated

15 error of generated warping of the second scanning
lens 1030, the reflection mirror 1023, the
cylindrical lens 1024, the polygon mirror 1026, the
first scanning lens 1028, the reflection mirrors 1031
and 1032, and flatness of the second scanning lens

20 1030, and so on. However, even if the scanning line
is curved by these causes, the scanning line curve
correcting means 1071 bends only the second scanning
lens 1030 in the sub scanning direction so as to
resolve the scanning line curve.

25   For example, when the second scanning lens

1030 is warped upwards, the pressing member of the
scanning line curve correcting mechanism 1081
provided at the center part of the second scanning
lens 1030 is pressed downwards to press the second

5   scanning lens 1030. On the other hand, when the
second scanning lens is warped downwards, the
pressing members of the scanning line curve
correcting mechanisms 1081 provided at the both end
parts of the second scanning lens 1030 is pressed

10 downwards to press the second scanning lens 1030. In
reality, an amount of the scanning line curve is
about several tens μm, so that the scanning line
curve can be corrected without deforming the
supporting member 1063 and the sandwiching support

15 member 1064.

As shown in FIG. 18, at the time of forming
the second scanning lens 1030 by molding, a
depression part 1083 is formed on the surface of the
second scanning lens 1030 that contacts with the

20 pressing member 1073. The depression part 1083 has a
width "d" along the thickness of the second scanning
lens 1030 in the optical axis direction C. The
length of the pressing member 1073 in the optical
axis direction C is longer than the width "d" of the

25 depression part 1083 so that contact between the

pressing member 1073 and the second scanning lens 1030 can become stable.

Furthermore, the axial direction of the pressing member 1073 is parallel to the optical axis of the second scanning lens 1030. Accordingly, even when an environmental temperature changes, and the second scanning lens 1030 is contracted or expanded, the pressing member 1073 is rotated, or slides on the surface of the second scanning lens 1030. As a result, the pressing member 1073 does not prevent the expansion or contraction of the second scanning lens in the direction A so that change of the optical characteristics of the second scanning lens 1030 can be suppressed. Moreover, in a case where it is intended that an amount and direction of the warping (the scanning line curve) is made uniform between the respective stations, the scanning line curve correcting means deforms the second scanning lens 1030 together with the supporting member 1063, and the sandwiching support member 1064 so that an adjustment margin can be improved, facilitating the adjustment.

As shown in FIG. 16, scanning line inclination correcting means 1072 includes a stepping motor 1090 as an actuator that is integrated with the

sandwiching support member 1064, and drives the holding member 1061 to be tilted. That is, the stepping motor functions as holding member tilting means and driving means. The scanning line

5 inclination correcting means 1072 further includes inclination detecting means (not shown) for detecting an inclination of the scanning line. The scanning line inclination correcting means 1061 further includes a CPU as control means (not shown) that

10 causes the stepping motor 1090 to tilt the holding member 1061 in accordance with a position displacement amount of the scanning line detected by the inclination detecting means so that the entire second scanning lens 1030 can be tilted to correct

15 the scanning line inclination.

In FIGS. 16 and 17, the reference number 91 designates a long lens holder integrated with a housing (not shown) of the light scanning device 1020. The long lens holder 1091 is a fixed member that

20 supports the holding member 1061. The long lens holder 1091 may be the housing itself of the light scanning device 1020. The long lens holder 1091 includes a V-shaped groove 1092 formed such that the groove 1092 extends in the direction C. The groove

25 1092 corresponds to the center of the second scanning

lens 1030.

The scanning line inclination correcting means may include a rolling member 1093 that is long in the direction C, and that functions as a

5 supporting point. The holding member 61 is supported by the long lens holder 1091 via the roller member such that the holding member 61 can move. Accordingly, a contacting part between the roller member 1093 and the holding member 1061 functions as

10 the supporting point 1047. The supporting point 1047 is positioned at the center of the second scanning lens 1030 in the direction A, and is positioned near the optical axis of the second scanning lens 1030.

If the long lens holder 1091 supports the

15 holding member 1061 only via the roller member 1093, the holding member 1061 is unstable. The scanning line inclination correcting means 1072 includes a leaf spring 1094 that is an elastic member configured integrally with the supporting member 1063 and the

20 long lens holder 1091. The scanning line inclination means 1072 further includes a leaf spring 1095 that is an elastic member 1095 configured integrally with the sandwiching member 1064 and the long lens holder 1091. The scanning line inclination means 1072

25 supports the holding member such that the holding

member 1061 can be moved relative to the long lens

holder 1091 in the direction of correcting the

scanning line inclination. An elastic force presses

the holding member 1061 against the roller member

5   1093 to stabilize the holding member 1061 to the long

lens holder 1091.

By means of screws, the leaf spring 1094 is

integrated with the supporting member 1063 and the

long lens holder 1091. By means of screws 1097, the

10   leaf spring 1095 is integrated with the sandwiching

support member 1064 and the long lens holder 1091.

As shown in FIGS. 16 and 20, by means of screws 1093,

the stepping motor 1090 is integrated with the

sandwiching support member 1064. In this example,

15   the stepping member 1090 is provided at the side of

the holding member 1061 that is driven by the

stepping motor 1090. However, the stepping motor

1090 may be provided at the long lens holder 1090, or

may be provided at the housing of the light scanning

20   device 1020.

As shown in FIG. 20, the stepping motor 1090

includes a stepping motor shaft 1099. A protruding

part 1043 is provided on an upper surface of the long

lens holder 1090. A groove part 1044 is defined by

25   an inside of the protruding part 1043. A nut of

which leading edge has a spherical shape and of which

section has an elliptic shape engages the groove 1044.

The stepping motor shaft 1099 has a male screw thread,

and a leading edge part of the stepping motor shaft

5 1099 engages the nut 1045. The nut 1045 engages the

groove 1044 to be fixed, and even at the time the

stepping motor shaft 1099 rotates, the nut 1045 is

not moved.

Inclination detection means is photo sensor

10 that reads a test pattern formed at a region of the

transfer belt 5 where paper does not pass. As for

the test patter, toner image having the same shape is

formed on each of the photoconductive bodies 1A

through 4A, and these toner images are transferred to

15 the region of the transfer belt 1005 where the paper

does not pass, at respective timings by which the

these images overlap each other on the transfer belt

1005. However, when the scanning line is inclined,

the test patters formed by the photoconductive bodies

20 1A through 4A are displaced (shifted) from each other.

The inclination detection means detects this

displacement of the test patterns.

Based on the position displacement of the

scanning line detected by the inclination detection

25 means, a CPU calculates the number of steps to be

driven by the stepping motor 1090, and drives the stepping motor 1090. The test patterns are formed at an appropriate timing. The formation of the test patterns are used in feedback control performed by the CPU based on a detection signal of the inclination detection means. The test patterns formed on the transfer belt 5 are removed by the cleaning device 13.

According to the inclination correcting means having the above-described configuration, when based on a detection result of the inclination detection means, the CPU drives the stepping motor 1090 to rotate the stepping motor shaft 1099, the holding member 1061 is moved relative to the unmoved member 1091 against spring forces of the leaf springs 1094 and 1095 so that the holding member 1061 is inclined by rotating around the support point 1047 in the γ direction shown in FIG. 22 as $\Delta \gamma$ and the arrow. Based on the detection result of the inclination detection means, the CPU performs the feedback control to drive the stepping motor 1090, so that the position displacement of the scanning line, specifically, the inclination of the scanning line can be resolved promptly.

Since the support point 1047 is positioned

near the optical axis of the second scanning lens

1030, it is possible to suppress the optical

characteristics change when correcting the scanning

line inclination by tilting the second scanning lens

5   1030. Independent of each other, the scanning line

curve correcting means 1071 and the scanning line

inclination correcting means correct the scanning

line curve and the scanning line inclination so that

each of the scanning line curve and inclination can

10   be separately corrected.

As described above, in order to correct the

scanning line curve and the scanning line inclination,

the position of the scanning line at each of the

scanning optical systems corresponding to the

15   respective colors may be adjusted such that the

displacement amount when putting the respective

scanning line on top of one another on the transfer

belt 5 can become zero. However, when correcting the

respective scanning position positions corresponding

20   to light beams of the four colors, if all of the four

scanning positions are adjusted to the standard

position, there is a possibility that the second

scanning leans 1030 is wrongly rotated by a large

amount, resulting in deterioration of the optical

25   performance and the beam spot diameter. Furthermore,

the number of the components and the cost are
increased because the scanning line curve correcting
means and the scanning line inclination means are
provided for each of the beams of the four colors.

5   For this reason, in the light scanning
device 1020, one of the four colors yellow Y, magenta
M, cyan C, and black K is set as a standard color.
The scanning positions of the scanning beams of the
scanning optical systems other than the standard

10   color are adjusted so as to approximately conform to
the scanning position of the standard color. In
other words, the scanning beams other the scanning
beams corresponding to the standard color are made to
conform with the scanning beam corresponding to the

15   standard color. Thus, the relative positions of the
scanning lines may be adjusted so that high
reproductive performance for an image can be realized
with the color tone change being sufficiently
suppressed. In this manner, the necessary number of

20   sets of the scanning line curve correcting means 1071
and the scanning line inclination correcting means
1072 becomes three to adjusts three scanning beams of
the four scanning beams for yellow Y, magenta M, cyan
C, and black K.

25   In this example, the standard color is black

K. A color image can be formed basically by the three colors Y, C, and M. However, the black color is generally used in order to improve sharpness of a color image, resolution of a character image. Also

5 in this example, the black color is used. By setting a black color as the standard color, the following advantage can be obtained.

The contrast of the black color higher than the contrasts of the other colors, so that the

10 deterioration (caused by vibration and temperature change) of accuracy of the beam spot and the beam spot position for the black color affects the image more than the other colors. Accordingly, the rigidity of the optical components of the scanning

15 optical system for the standard color can be strong so that this scanning optical system can be less affected from outside factors such as vibration and temperature change. Next to the black color, magenta M has the nature similar to that of the black color,

20 so that magenta M may be set as the standard color. Additionally, yellow Y or cyan C may be set as the standard color.

With such a configuration, it is necessary to adjust three colors, so that the three sets of the

25 scanning line curve correcting means 1071 and the

scanning line inclination correcting means 1072
suffice. Furthermore, the adjustment points and the
adjustment amount can be reduced, so that the
relative color difference can be easily corrected
5   even when the scanning lines are largely displaced
from the scanning line of the standard color.
Therefore, it is possible to correct the color
difference less than one line, and to realize high
color reproductive performance with the color tone
10   change being sufficiently suppressed. With this
configuration, by suppressing the relative color
difference amount up to less than 30 μm, it is
possible to form the image in which the color
difference is not noticeable.

15   As shown in FIGS. 21 and 22, the writing
start position adjusting means 1140 includes a prism
1101, a stepping motor 1109 that rotates the prism
1101 for adjustment, and a lead screw type actuator
1102 that uses the stepping motor 1109 as a driving
20   resource. Since the writing start position adjusting
means 1140 and 1141 has the same configuration, only
the writing start position adjusting means 1140 will
be described as representative.

        Principle of the beam spot position
25   adjustment by the wedge-shaped prism 1101 in the sub

scanning direction will be described. The prism 1101 is wedge-shaped. The symbol O-O designates the optical axis of the beam that penetrates through the prism 1101. By rotating the prism 1101 approximately

5   around the optical axis O-O as indicated by the arrow 1103, it is possible to deflect the incident light beam within the range of the maximum deflection angle ϕ as indicated the arrow 1104. As a result, the beam spot position on the scanned surface can be adjusted

10 in the sub scanning direction.

As shown in FIG. 21, by rotating the prism 1101 around the optical axis O-O, the light beam can be deflected within the range of the maximum deflection angle ϕ by the effect of the beam

15 refraction. If an apex angle of the prism 1101 is α, and the refraction index of the wedge-shaped prism 1101 (prism glass material) is n, the maximum deflection angle can be expressed by the following equation (1):

20          $\phi = (n - 1) \times \alpha \quad \cdots (1)$.

Furthermore, in a case where the optical axis O-O conforms with the optical axis of the LD unit 1021 or 1022, if the focal length of the collimating lens 1150b is fc, the transversal

25 magnification rate in the sub scanning direction is β,

and the rotation amount of the prism 1101 is γ, the scanning position correcting amount P on the surface of the photoconductive body can be expressed by the following equation (2):

5          $P = fc \times \beta \times \tan\phi \times \sin\gamma \cdots (2)$.

Preferably, the apex angle α (deg) of the prism 1101 satisfies the following relation (3):

$0.1 < \beta \times \tan[(n-1) \times \alpha] < 1.0 \cdots (3)$.

In the relation (3), when the apex angle
10 becomes higher than the upper limit, the wavefront aberration is generated in the light flux, the shape of the beam spot is disturbed (side lobe generation), or the beam spot diameter becomes large. When the apex angle α becomes lower than the lower limit, the
15 sensitivity is badly deteriorated, so that it becomes necessary to rotate the prism 1101 by large amount. Accordingly, in this case, it is impossible to perform operation at high speed response at the time of correcting the optical characteristics change
20 caused by the time lapse, or the like.

As shown in FIG. 22, the actuator 1102 includes a prism holder 1105 to which the prism 1101 is attached. An arm 1105a is formed at a part of the prism holder 1105. The prism holder 1105 is
25 supported via the arm 1105a such that the prism

holder 1105a can rotates around the optical axis O-O
of the collimating lens. One end of a compressed
spring 1106 contacts with an upper surface of a free
end side of the arm 1105a. The compressed spring

5   1106 is positioned between the fixed members so that
the compressed spring 1106 presses the arm 1105a. By
this structure, the clockwise moment for driving the
prism holder 1105 and the prism 1101 to rotate
clockwise (in FIG. 9) around the optical axis O-O of

10   the prism 1101 is applied to the prism holder 1105.

The rotation of the prism holder 1105 caused
by this moment is received by a receiving member 1107
that contacts with a lower surface of the free end
part of the arm 1105a. The receiving member 1107 is

15   an axial member having a cylindrical shape. An upper
side end part of the receiving member 1109 are formed
as a circular cone as shown in FIG. 22. The contact
point between the lower surface of the free end part
of the arm 1105a and the receiving member 1107 is

20   referred to as an application point P of the actuator.

Meanwhile, at the opposite side to the
circular cone of the receiving member 1107, a nut
1108 is fixed (or, female screw thread is formed). A
male screw (referred to as a lead screw) integrated

25   with a lead screw of a rotational shaft of the

stepping motor 1109 engages the nut 1107. The stepping motor 1109 is fixed to a fixed member (not shown).

The above-described rotating member is referred to as a lead screw type actuator. By driving the stepping motor 1109, the prism 1101 is rotated together with the prism holder 1105 around the optical axis O-O of the prism 1101. Since the lead screw type actuator uses the stepping motor 1109 as a driving resource, the rotation angle of the prism 1101 can be controlled by a digital pulse signal. Therefore, after a position displacement amount is calculated by a micro computer, feedback control can be easily performed by a pulse signal.

The movement amount Δx by the lead screw type actuator (= the movement amount of the nut = the movement amount of the application point P) can be obtained by the following equation (4):

$$\Delta x = R \times \tan(\Delta \gamma) \quad \cdots (4).$$

R designates a distance from the rotation center to the application point P of the actuator), and $\Delta \gamma$ designates the rotation angle of the prism 1101.

Time Tm required for performing one rotation of the transfer belt 5 can be expressed by the

following equation (5)

$$Tm = Lm/Vm \text{ (sec)} \quad \cdots (5).$$

Lm designates the one-rotation length of the transfer belt 5, and Vm designates the linear velocity of the transfer belt 5.

Accordingly, a driving frequency N per second for the stepping motor 1109 that is required for the correcting amount ΔZ in the sub scanning direction on the photoconductive bodies 1A through 4A can be obtained by the following equation (6):

$$N = (\Delta x/p) \times (N0/Tm) \quad \cdots (6).$$

p designates a screw pitch of the lead screw, and N0 designates the number of pulses per one rotation of the stepping motor 1109.

A color difference can be sufficiently reduced by satisfying the following equation (7):

$$10 < N < 2000 \text{ (pps)} \quad \cdots (7).$$

When N becomes larger than the upper limit 2000 pps, in a preferable case, N becomes larger than 1000 pps, the stepping motor cannot respond, so that the correcting of the beam spot position displacement cannot be followed. On the other hand, when N becomes lower than the lower limit 10 pps, the resolution becomes very rough, so that accuracy in correcting of the beam spot position displacement is

insufficient.

The torque of the stepping motor 1109 can be expressed by the following equation (8):

$$T = T1p/2\pi R \quad \cdots (8).$$

5   P designates the screw pitch of the lead screw, T1 designates the torque generated by the tension of the spring 1106, and R designates the distance between the rotation center and the application point P.

10   The maximum response pulse number Nmax of the stepping motor 1109 can be read from pull-in driving frequency to torque T by using a standard table (motor characteristics) as shown in FIG. 24. Accordingly, in order to control the sub scanning

15   direction correcting amount ΔZ in the equation (6) on the photoconductive body 1A through 4A, the necessary number of pulses per second needs to satisfy the following condition (9):

$$N < Nmax \quad \cdots (9).$$

20   The apex angle α of the prism 1101 is set to an appropriate angle by the actuator 1102 so as to set appropriate sensitivity. In this manner, it is possible to realize a fine beam spot position without too high sensitivity as in galvanometer mirror method,

25   or with the beam spot position being less affected by

vibration. Furthermore, by using the wedge-shaped
prism 1101, the operation control can be simplified
because the wedge-shaped prism 1101 having the simple
structure is rotated. Different from position

5   correcting control per batch at the time of starting
up the machine, or before print out, in this
embodiment, it is possible to correct the beam spot
position while writing the image data.

       Accordingly, even when the temperature is

10   rapidly changed, or when the position displacement is
generated by the speed change of the transfer belt 5
or the photoconductive body such as during a
starting-up section A, or during a successive print
section indicated by "B", as shown in FIG. 25, it is

15   possible to perform almost real time position
correcting based on position displacement data from
the beam spot position detection means 1300a and
1300b (shown in FIG. 23), and the color difference
detection sensor 1330. As a result, it is possible

20   to greatly reduce the color difference generation.
In stead of, or in addition to the above-described
scanning line inclination detection means, the beam
spot position displacement means 1300a and 1300b, and
the color difference detection sensor 1330 may be

25   used as the scanning line inclination means.

By selecting a material (for example, resin) or a shape (for example, a thin shape), the weight of the wedge-shaped prism 1101 and the prism holder 1105 can be made relatively light. Compared with a

5   conventional case where relatively heavy optical elements such as a long reflection mirror, a scanning lens, a roof prism, and a light source unit are tilted/shifted to correct the beam spot position, in this embodiment, the response speed is higher, and

10   the position displacement can be corrected up to higher frequency.

Furthermore, compared with a case of a liquid crystal deflection element or electric optical element (PLZT) where an applied voltage is changed to

15   correct the beam spot position, in this embodiment, a relative color difference amount can be suppressed to less than 30 μm, realizing a state where actual color difference is not noticeable.

The light scanning device 1020 includes at

20   least one prism 1101 in an optical path between the LD units 1021 and 1022 and the polygon mirrors 1026 and 1027. The light scanning device 1020 includes the above-described writing start position adjusting mean 1140 that rotates the prism 1101 around the

25   optical axis to adjust the beam spot position in the

sub scanning direction on the photoconductive body 1A

through 4A. The light scanning device 1020 further

includes the position displacement detection means

for detecting the relative writing start position

5   displacement in the sub scanning direction on the

photoconductive body 1A through 4A. Further, by the

light scanning device 1020, based on the position

displacement data from the position displacement

detection means, it is possible to perform the

10   feedback control on the writing start position

adjusting means 1140. The sub scanning direction on

the photoconductive body 1A through 4A corresponds to

the direction indicated by the arrow B in the

drawings, but in the same space, these directions are

15   different from each other.

As shown in FIG. 23, the position

displacement detection means may include the beam

spot position detection means 1300a for detecting the

writing start position, the beam spot position

20   detection means 1300b for detecting the writing end

position, and the color difference detection means

1330. By this position displacement detection means,

it is possible to correct writing start position in

the sub scanning direction on the photoconductive

25   body 1A through 4A when the position is displaced by

the time lapse. The feedback control of the rotation adjustment of the prism 1101 can be easily performed by the stepping motor or a supersonic motor.

At the time of printing the predetermined number of pages, the beams for forming the color difference detection toner images are emitted from the LD units 1021 and 1022. Thereby, as shown in FIG. 23, the color difference detection toner images 1330 can be formed, respectively, at three points on the transfer belt 5. The color difference can be detected based on these toner images by using the color difference detection means 1330.

The light scanning device 1020 is configured such that the beam spot position detection means 1300a and 1300b as the position displacement detection means may be supported by a case-shaped optical housing (not shown). Furthermore, in the light scanning device 1020, the color difference detection means 1330 provided at the side of the main body of the image forming apparatus 1 may be used as the position displacement detection means, and may be used to obtain the correcting amount of the writing start position correcting means 1140, and may be used together with the beam spot position detection means 1300a and 1300b.

In a case where the color difference detection means 1330 is used together with the beam spot position displacement detection means 1300a and 1300b, the color difference detection means 1330 may

5   used for rough adjustment, and the beam spot position displacement detection means 1300a and 1300b may used for fine adjustment. Based on the position displacement detection result, the writing start position correcting means 1140 performs correcting

10   control on the beam spot positions on the photoconductive bodies 1A through 4A while writing image data.

As shown in FIG. 25, in a case of printing a plurality of pages of images, in the light scanning

15   device 1020 heat is generated from a motor that drives the polygon mirrors 1026 and 1027, and the LD units 1021 and 1022, and outside the light scanning device 1020, heat is generated from the heater of the fixing device 14 at the time of fixing operation.

20   Accordingly, a temperature in the image forming apparatus 1 is rapidly raised. In this case, the beam spot position on the photoconductive bodies 1A through 4A are also rapidly changed, so that the color tone of an output color image is gradually

25   changed as the number of printed pages increases to

one page, several pages, and tens of pages.

For this reason, by using the beam spot position displacement detection means 1300a and 1300b, and the color difference detection means 1330 as the position displacement detection means, the writing start position adjusting means 1140 performs adjustment. The beam spot position detection means 1300a and 1300b are non parallel photo diode sensors. The beam spot position detection means 1300a and 1300b also have a function of detecting a synchronization signal for determining a writing start position in the main scanning direction.

As shown in FIG. 26, light receiving surfaces of the photo diodes PD1 and PD1' are orthogonal to the scanning beam, and light receiving surfaces of the photo diodes PD2 and PD2' are inclined from the light receiving surfaces of the photo diodes PD1 and PD1'. $\alpha 1$ in FIG. 26 designates an inclination angle by which the receiving surfaces of the photo diodes PD2 and PD2' are inclined from the light receiving surfaces of the photo diodes PD1 and PD1'. Further, in FIG. 26, L1 designates a scanning beam before a temperature is changed by the heater, and L2 designates a scanning beam after a temperature is changed by the heater. It is assumed

that the position is displaced by the distance ΔZ (unknown) in the sub scanning direction. In this case, time T1 and T2, required by the scanning beams L1 and L2 to pass between a pair of the non-parallel photo diodes PD1 and PD2, or between a pair of the non-parallel photo diodes PD1' and PD2', are measured. A time difference "T2 - T1" is calculated. In this manner, the scanning position, that is, the writing start position is monitored and detected.

The relative dot position displacement in the sub scanning direction, that is, the correcting amount ΔZ in the sub scanning direction can be easily calculated because the inclination angle $\alpha 1$ made by the light receiving surfaces of the photo diodes PD1 and PD2, and the time difference "T2 -T1" are known values. Accordingly, the writing start position adjusting means 1140 adjusts and corrects the scanning position by the correcting amount ΔZ. Therefore, in a case of printing a plurality of pages of images, even when the beam spot positions on the photoconductive bodies 1A through 4A are rapidly changed by the temperature change, for example, it is possible to correct the beam spot positions on the photoconductive bodies 1A through 4A even during image writing. Furthermore, by detecting change of

time T0 required by the scanning beam to pass between
the photo diodes PD1' and PD1, it is also possible to
monitor the magnification change in the main scanning
direction.

5   FIG. 27A shows dot position change in the
sub scanning direction on the transfer belt 5. As
understood from FIG. 27A, the dot position
displacement ΔZ in the sub scanning direction is
periodically generated on the transfer belt 5. This
10 period of the dot position displacement generation
corresponds to time Tm required by the transfer belt
5 to rotate once. This time Tm can be obtained by
the above-mentioned equation (5), and preferably
satisfies the following relation (10):

15          $0.5 < Tm < 5$ (sec) $\cdots$ (10).

          In the relation (10), when the time Tm
becomes larger than the upper limit, the scanning
position can be easily affected by an outside
disturbing factor such as vibration because the one
20 period is too long. Meanwhile, when the time Tm
becomes lower than the lower limit, high speed
response is required for the beam spot position
correcting control, so that the rotation speed of the
prism 1101 cannot follow the required response speed.
25 When the Tm satisfies the relation (10), the scanning

position is less affected by the outside disturbing factor such as vibration, and the rotation speed of the prism 1101 can appropriately follow the required response speed.

5   Fig. 17B shows the dot position displacement in the sub scanning direction after the beam spot position correcting is performed according to this embodiment of the present invention. Since the above-mentioned position displacement amount Δz is a

10 correcting amount in the sub scanning direction, the dot position displacement on the transfer belt 5 is corrected by correcting the beam spot position at the writing optical system. Thereby, as shown in FIG. 27B, low frequency large position displacement

15 component is sufficiently corrected. Additionally, as shown in FIG. 27B, position displacement of very high frequency cannot be corrected. In the example of FIG. 1, a middle transfer body is configured as the transfer belt 5, but the middle transfer body may

20 be configured as a drum type transfer body. Also in this case of the drum type transfer body, according to this embodiment, it is possible to adjust the position displacement in the same manner.

As described above, in order to correct a

25 color difference in the sub scanning direction, there

is one method of making a displacement amount zero

when putting, on top of one another on the transfer

belt 5, the scanning line positions corresponding to

the respective colors. This method may be adopted.

5   However, at the time of adjusting writing start

positions, that is, scanning positions of the

respective laser beams corresponding to the

respective colors, when all of the four light beams

are adjusted to a predetermined standard position,

10   there is a possibility that a large rotational

decentering is wrongly applied, resulting in

degradation of the optical performance such as a beam

spot diameter. Furthermore, in this method, the

number of the components of the writing start

15   position correcting means is increased, raising cost.

For this reason, according to the light

scanning device 1020 of this embodiment, one of the

four colors of yellow Y, magenta M, cyan C, and black

K may be set as the standard color, and the scanning

20   beam operated by the scanning optical system for the

colors other than the standard color may be adjusted

to conform with the scanning line position of the

standard color. In other words, the scanning lines

of the non-standard colors may be adjusted to conform

25   with the scanning line of the standard color. Thus,

by correcting relative color difference, it is possible to realize high color reproduction performance of an image with color tone change being sufficiently suppressed.

5   Thus, it is sufficient that the prisms 1101 for correcting the writing start position are arranged such that three scanning lines of the four scanning lines of yellow Y, magenta M, cyan C, and black K are adjusted. Accordingly, the three prisms

10   1101 suffice, and the three writing start position adjusting means 1140 suffice.

In this case, the scanning beams may penetrate through air instead of the prism 1101, and the writing start position adjusting means 1140

15   integrated with the prism 1101 may be arranged for the scanning beams of the three colors other than the standard color.

In this embodiment, as one example, the standard color is black. A color image can be

20   generally formed by using three colors Y, M and C. However, in order to improve sharpness of the color image, and improve resolution of a character image, for example, a black color is generally used, so that also in this embodiment, a black color may be used.

25   In this case, by setting the black color as the

standard color, the following advantage can be obtained.

The contrast of the black color is higher than the contrast of the other colors. In the case

5 of the black color, degradation of a beam spot diameter, and a beam spot position change that are affected by the outside disturbing factor such as vibration and temperature change are more visible in the formed image other than the other colors. For

10 this reason, by setting the black color as the standard color, it is possible to provide high rigidity for the optical components of the scanning optical system that handles the standard color so that the scanning optical system for the standard

15 color of the black color can be less affected by the outside disturbing factor. Next to the black color, magenta M has this nature similar to black K, so that magenta M may set as the standard color. However, another color may be set as the standard color.

20 With such a configuration, adjustment targets may be three colors of the four colors, and the necessary number of the prisms 1101 may be three. Accordingly, adjustment points and adjustment amount can be decreased, so that the scanning position

25 displacement from the standard color scanning

position is large, it is possible to easily correct the relative color difference. In this manner, it is possible to correct a color difference less than one line, and to obtain high color reproduction

5 performance with color tone change being sufficiently suppressed. As described above, according to this embodiment of the present invention, by suppressing a relative color difference amount (or, a position displacement amount) to less than $30\mu m$, it is

10 possible to realize a condition in which an actual color difference is sufficiently less visible.

In the following, modification examples of the scanning line curve correcting means 1071 and the scanning line inclination correcting means 1072 will

15 now be described. It should be noted that, any combination among the modification examples may be used. The present invention is not limited to the following modification examples.

As shown in FIGS. 28 through 30, the

20 reference surface 1065 may be formed so as to correspond to a part other than the part pressed by the scanning line curve correcting means 1071, that is, may be formed so as to corresponding to the part that is not pressed by the scanning line curve

25 correcting means 1071. In the example of FIG. 28,

the reference surfaces 1065 are formed by two
protruding parts 1111 having a height of 200μm. The
protruding parts 1111 may be formed by performing a
squeezing process on the supporting member 1063 that

5   is a metal plate. Upper surfaces of the protruding
parts 1111 is the reference surfaces 1065. Each of
the protruding parts 1111 is formed between the
scanning line curve correcting mechanisms 1081
arranged in the main scanning direction A.

10   By this configuration of FIG. 28, at each of
positions pressed by the scanning line curve
correcting mechanisms 1081, a space having a height
of 200 μm is formed between the lower surface of the
second scanning lens 1030 and the main body of the

15   supporting member 1063. At the time the scanning
line curve correcting mechanism 1081 presses the
second scanning lens 1030, this space functions as an
evacuating space for the second scanning lens 1030 so
that the second scanning lens 1030 can be moved

20   appropriately in the direction B, that is, a good
correcting operation can be performed. Compared with
the case as shown in FIG. 17 and so on where the
reference surface 1065 exists also at the position
pressed by the scanning line curve correcting

25   mechanism 1081, a smaller stress (force) enables the

correcting operation, so that the good correcting operation by the scanning line curve correcting mechanism 1081 can be performed easily.

In order to form the reference surface 1065

5   corresponding to the part that is not pressed by the scanning line curve correcting mechanism 1081, a depression part may be formed on the supporting member 1063 at the part that is pressed by the scanning line curve correcting mechanism 1081. The

10 present invention is not limited to the cases of FIGS. 28 through 30 where the protruding part is formed for the reference surface 1065. In other words, unevenness may be formed on the supporting member 1063 such that the reference surface 1065 is formed

15 by the protruding part at the part that is not pressed by the scanning line curve correcting mechanism 1081. Furthermore, the reference surfaces 1065 may be formed at further both end sides of the supporting member 1063 compared with the positions of

20 the both end side scanning line curve correcting mechanisms 1081. When four scanning line curve correcting mechanisms 1081 are provided, three or five reference surfaces 1065 are formed, and five scanning line curve correcting mechanisms 1081 are

25 provided, four or six reference surfaces 1065 are

formed.

When unevenness is formed on the supporting
member 1063, and both ends of the second scanning
lens 1030 are positioned at the depression parts of
5 the supporting member 1063, it is possible to set a
height of the pillar 1066 such that the level of the
upper surface of the pillar 1066 is lower than the
level of the upper surface of the second scanning
lens 1030. For example, the height of the pillar
10 1066 is not equal to the thickness of the second
scanning lens 1030, but the height of the pillar 1066
can be smaller than the thickness of the second
scanning lens 1030.

In this case, when the second scanning lens
15 1030 is sandwiched and supported by the supporting
member 1063 and the sandwiching support member 1064,
an upward force that deforms the second scanning lens
1030 upwards is always applied to the second scanning
lens 1030 at an initial state before the scanning
20 line curve correcting means 1071 performs the
correcting operation. Therefore, the protruding
parts can be formed on the supporting member 1063,
and the height of the pillar 1066 can be smaller than
the thickness of the second scanning lens 1030 such
25 that the initial state before the scanning line curve

correcting means 1071 performs the correcting operation is uniform or constant. The curve correcting operation can be standardized.

Since the supporting member 1063 is also
5   elastically deformed by a small reactive force, the deformed amount of the second scanning lens 1030 becomes equal to or less than 100 μm. The height of the pillar 1066 enable the state where the upward force for deforming the second scanning lens 1030
10   upwards is always applied to the second scanning lens 1030 when the second scanning lens 1030 is sandwiched and supported by the supporting member 1063 and the sandwiching support member 1064 in the initial state before the scanning line curve correcting means 1071
15   performs the correcting operation. This deformation of the second scanning lens 1030 before the correcting operation can be corrected by the scanning line curve correcting means 1071.

As shown in FIG. 31, instead of the leaf
20   springs 1094 and 1095, compressed springs 1112 that are coil springs may be used as elastic members that are configured integrally with the holding member 1061 and the fixed long lens holder 1091, and that supports the holding member 1061 such that the
25   holding member 1061 can move relative to the long

lens holder 1091 in the direction of correcting the scanning line inclination. Pillars 1114 provided at the both end parts of the long lens holder 1091 are integrated with the long lens holder 1091 so as to

5 protrude toward the lower surface of the sandwiching support member 1064. Screws 1113 having steps engage the long lens holder 1091.

The screws 1113 penetrate through the sandwiching support member 1064 so as to engage the

10 pillars 1114. The compressed springs 1112 are wound around the part between the sandwiching support member 1064 and screw heads 1113a of the screws 1113. Upper ends of the compressed springs 1113 engage lower surfaces of the screw heads 1113a, and lower

15 ends of the compressed springs 1112 engage the upper surface of the sandwiching support member 1064.

Spring force of the compressed springs 1112 drives the screw heads 1112 and the sandwiching support member 1064 in the direction of drawing them

20 to each other. Thus, the compressed springs 1112 are substantially integrated with the long lens holder 1091 via the screws 1113 having the steps.

Accordingly, the spring force of the compressed springs 1112, and the long lens holder

25 1091 supports the holding member 1061 via the roller

1093 such that the holding member 1061 can be moved relative to the long lens holder 1091 in the direction of correcting the scanning line inclination. Further, in this manner, the holding member 1061 can be supported in the holding member 1061 being stable to the long lens holder 1091.

The function of the coil spring (for example, the compressed spring 1112) is that the holding member 1091 is supported such that the holding member 1061 can be moved relative to the long lens holder 1091 in the direction of correcting the scanning line inclination, and that the holding member 1061 is stable to the long lens holder 1091. Accordingly, instead of the compressed spring 1112, it is possible to use any means for supplying force in the direction of drawing the screw heads 1113a and the sandwiching support member 1064 to each other, and supplying force in the direction of separating sandwiching support member 1064 and the long lens holder 1091.

By adjusting the connection state of the springs 1113 such that force applied by the springs 1113 can be optimized, it is possible to correct the scanning line inclination by a predetermined amount, using the holding member tilting means such as the stepping motor 1090. The elastic member may be a

torsion beam, or a combination of the leaf spring, the coil spring, and the torsion beam.

As shown in FIG. 32, instead of the stepping motor 1090 shown in FIG. 17, the holding member tilting means may be a screw 115 for correction in the γ direction. In the example of FIG. 32, the sandwiching support member 1064 includes an inclination part 1116 that is bent in an oblique direction toward the long lens holder 1091 so as to extend at one end of the sandwiching support member 1064. The sandwiching support member 1064 further includes a beam part 1117 that extends at the other end of the sandwiching support member 1064. One end part of the beam part 1117 is fixed to the long lens holder 1091 by screws 1097. The beam part 1117 functions as an elastic member. By making a part of the sandwiching support member 1064 thin, the beam part 1117 is formed integrally with the sandwiching support member 1064. The screw 1115 engages the inclination part 1116 so as to be integrated with the sandwiching support member 1064. A front end of the screw 1115 engages the long lens holder 1091, and a compressed spring 1118 is wound around the screw 1115 between the inclination part 1116 and the long lens holder 1091.

In this example, by using balance between
the spring force of the compressed spring 1118, and
the elastic region and flexure of the beam part 1117,
appropriately fastening the screw 1115 enables the
5   fine adjustment. Without performing the feedback
control, and without using the stepping motor 1090,
the tilting adjustment can be performed by using the
screw 1115. In this manner, the initial adjustment
can be performed, or in accordance with a necessity,
10 adjustment can be performed by a service person to
greatly reducing cost. As described, the elastic
member may be configured by the beam part as in this
example. Furthermore, the elastic member may be
configured by a combination of the leaf spring, the
15 coli spring, and the beam part, for example.

In the example of FIG. 17, the scanning line
curve correcting means 1071 includes the plural
scanning line curve correcting mechanisms 1081 that
are the pressing means, and are arranged in the
20 longitudinal direction of the supporting member 1063.
However, a single pressing means may be provided in
the longitudinal direction of the supporting member
1061. The pressing means is not limited to the
configuration such as the scanning line curve
25 correcting mechanism 1081 having the pressing member

1071.

In other words, as shown in FIGS. 33 and 34, the pressing means may include a single screw 1119 provided on the supporting member 1163. The pressing

5 means 1120 includes a protruding 1121 part that is provided at the approximate center part in the longitudinal direction of the supporting member 1063, and that engages the screw 1119. The protruding part 1121 protrudes from the upper surface of the

10 sandwiching support member 1064. By rotating the screw 1119, the screw 1119 is moved in the direction approximately parallel to the sub scanning direction B. The protruding part 1121 is provided for enabling good engagement with the screw 1119. Thus, the

15 pressing means 1120 is integrated with the sandwiching support member 1064.

By rotating the screw 1119 of the pressing means 1120, it is possible to adjust pressing force applied to the second scanning lens 1030 by the screw

20 1119 so that the curve of the second scanning lens 1030 can be corrected. In this manner, the configuration of the pressing means 1020 can be simplified by using the only the screw 1119 and the protruding part 1121. As a result, cost can be

25 greatly reduced. It is sufficient that the pressing

force applied to the second scanning lens 1030 can be
adjusted, so that the movement direction of the screw
1119 is not limited to the direction approximately
parallel to the sub scanning direction B, and may be
5   the direction including the sub scanning direction B.

In another example, as shown in FIGS. 35A
and 35B, a configuration having a screw 1122 and a
metal plate pressing member 1123 may be used as a
simplified configuration of the pressing means. The
10   pressing means 1124 shown in FIGS. 35A and 35B
includes curved parts 1125 and 1126 that is a part of
the sandwiching support member 1064, and that stand
from the sandwiching support member 1064 so as to be
an L-shaped. One end part 1123a of the metal plate
15   pressing member 1123 is positioned above the curved
part 1126 such that a space is provided between the
one end part 1123a and the curved part 1125. The
other end part 1123b of the metal plate pressing
member 1123 is positioned below the curved part 1126
20   such that the other end part 1123b engages the curved
part 1126. The center part of the metal plate
pressing member 1123 engages the second scanning lens
1030 so as to form a pressing part 1123c. The screw
1122 penetrates through the one end part 1123a and
25   the curved part 1125 so as to engage the metal plate

pressing member 1123 and the curved part 1125. By
rotating the screw 1122, the screw 1122 is moved in
the direction approximately parallel to the sub
scanning direction B. Thus, the pressing means 1124
5   is integrated with the sandwiching support member
1064.

By rotating the screw 1122 of the pressing
means 1124, a distance between the one end part 1123a
and the curved part 1125 can be adjusted so that the
10 pressing force applied to the second scanning lens
1030 by the pressing part 1123c can be adjusted. In
this manner, it is possible to correct the curve of
the second scanning lens 1030. Thus, by simplifying
the configuration of the pressing means, it is
15 possible to greatly reduce cost. The pressing means
1124 has the configuration that is more complicated
than that of the pressing means 1120, so that the
cost for the pressing means 1124 is slightly raised.
However, the pressing means has an advantage in that
20 the pressing operation is more stable than that of
the pressing means 1120. It is sufficient that the
pressing force to the second scanning lens 1030 can
be adjusted, so that the movement direction of the
screw 1122 is not limited to the direction
25 approximately parallel to the sub scanning direction

B, and may be the direction including the sub
scanning direction B. Additionally, a configuration
using a cam or the like may be used as a simplified
configuration of the pressing means.

5   In the case where a single pressing means is
provided on the sandwiching support member 1064, not
only the simplified configuration such as the
pressing means 1120 and 1124, but also the scanning
line curve correcting mechanism 1081 may be used.

10   Furthermore, in the case where a plurality of the
pressing means are provided in the longitudinal
direction of the supporting member 1063, the pressing
means is not limited to the scanning line curve
correcting mechanism 1081, and the simplified

15   configuration such as the pressing means 1120, 1124,
and so on may be used, or a combination of the
correcting mechanism 1081, the pressing means 1120
and 1124, and so on.

        FIG. 36 shows a comparison result among a

20   case where the pressing means is not provided, a case
where one pressing means is provided in the
longitudinal direction of the supporting member 1063,
and a case where three pressing means are provided in
the longitudinal direction of the supporting member

25   1063. This comparison result shows an amount of

scanning line curve from an ideal position. In FIG.
36, an image height designates a distance from a
reference position that is the center in the
longitudinal direction of a held optical element such
5   as the second scanning lens 1030. The value at the
reference position is zero.

        As apparent from FIG. 36, in the case where
the pressing means is not provided, and the
adjustment is not performed, there is generated a
10   chevron-shaped result in which the scanning line
curve has a peak at the center of the held optical
element, that is, at the zero image height. In the
case where one pressing means is provided at the
position corresponding to the zero image height, and
15   the adjustment is performed at this one position,
there is generated an M-shaped result of which center
corresponds to the center of the held optical element,
that is, the zero image height. In this case, the
curved amount is about half of the case where the
20   pressing means is not provided. Accordingly, it is
found that the limit of the adjustment accuracy in
the case where one pressing means is provided is the
about half, in terms of the scanning line curve
amount, in the case where the adjustment is not
25   performed.

Meanwhile, in the case where three pressing means are provided, and the adjustment is performed at three positions, there is generated a polygonal line result of which center is the center of the held

5   optical element, that is, the zero image height. In this case, the scanning line curve amount is less than several tens μm, so that the adjustment can be performed at further accuracy. Thus, by increasing the number of the pressing means, it is possible to

10   improve the accuracy in adjusting the scanning line curve. The result shown in FIG. 36 in the case where the pressing means is not provided was obtained by using the configuration in which the protruding part is formed on the supporting member 1063, and the

15   height of the pillar 1066 is smaller than the thickness of the second scanning lens 1030.

In this embodiment, and the modification examples, the both end parts of the holding member are elastically supported to the fixed member so that

20   the both end parts of the held optical element such as the second scanning lens 1030 can be elastically supported. As in this manner, a method of holding the held optical element by using the structure having a beam at one or both ends thereof, and

25   correcting the inclination of the scanning line by

using this structure is called a span band method. A
conventional method of adjusting the scanning line
inclination by changing tilt of a reflection mirror
is called a MUSIC method.

5   With reference to FIGS. 37 and so on,
effects to optical characteristics in both cases of
the span band method and the MUSIC method are
compared, and an advantage obtained by the span band
method will be described. A magnification error in
10   FIG. 37 is a rate of a beam spot size difference
between the center position on the image holding body
corresponding to the zero image height, and the end
position on the image holding body corresponding to
the end part of the held optical element.
15   Accordingly, as the magnification error is smaller,
the optical characteristics change becomes smaller at
the time of the adjustment, and the scanning
operation becomes better.

          As apparent from FIG. 37, when the scanning
20   line inclination correction of 700 μm is performed by
the span band method, the magnification error is
constant. On the other hand, when the scanning line
inclination correcting is performed by the
conventional MUSIC method, as the correcting amount
25   becomes larger, the magnification error becomes large,

and optical characteristics becomes more degraded.
IN other words, by using the span band method, it is
possible to greatly improve the optical
characteristics at the time of the correcting

5   operation, compared with the conventional MUSIC
method.   In FIG. 37, 50 mm is an optical path length.

FIG. 38A shows magnification errors when the
inclination correcting amount and the image height
are changed according to the span band method.   FIG.

10   38B shows magnification errors when the inclination
correcting amount and the image height are changed
according to the conventional MUSIC method.   Data of
FIG. 37 is based on data of FIGS. 38A and 38B.   PV in
FIGS. 38A and 38B designates a difference between the

15   maximum value and the minimum value of the
magnification error.   In FIG. 38A, PV is constant,
and in FIG> 38B, as the inclination correcting amount
becomes larger, PV becomes large.   Accordingly, as
understood from the results of FIGS. 38A and 38B, by

20   using the span band method, it is possible to greatly
improve optical characteristics at the time of the
scanning line inclination correcting, compared with
the conventional MUSIC method.

FIGS. 39 and 40 show comparison between a

25   beam spot diameter of a design center (standard)

value before the inclination correcting, and beam

spot diameters when the inclination adjustment of 700

μm is performed by the conventional MUSIC method and

the span band method. FIG. 39 shows change of a beam

5 spot diameter in the main scanning direction, and FIG.

40 shows change of a beam spot diameter in the sub

scanning direction. In both of FIGS. 39 and 40,

shown polygonal lines closer to the polygonal lines

of the design center value means less degradation of

10 the beam spot diameter.

In FIGS. 39 and 40, an allowable range, that

is, change of a beam spot diameter to the optical

path length is shown by "defocus". In each of FIGS.

39 and 40, two dotted lines show the upper allowable

15 limit value and the lower allowable limit value of

the beam spot diameter, respectively. As apparent

from FIGS. 39, the result of the span band method is

closer to the polygonal lines of the design center

value than the result of the conventional MUSIC

20 method. In other words, shapes of the polygonal

lines obtained by the span band method are

approximately same as those of the design center

value. Furthermore, the allowable range in the main

scanning direction of the MUSIC method is narrower

25 than that of the span band method. Accordingly, in

the span band method, there is generated less

degradation of the beam spot diameter in the main

scanning direction, and it is possible to realize

very excellent optical characteristics at the time of

5   the inclination correcting.

FIG. 40 shows similar tendency of FIG. 39

that is less than in FIG. 39. There is generated

little degradation of the beam spot diameter in the

sub scanning direction in the span band method.

10   Accordingly, in the span band method, the optical

characteristics in the sub scanning direction at the

time of inclination correcting are better than those

of the MUSIC method. As a result, as understood from

FIGS. 39 and 40, in terms of degradation of the beam

15   spot diameter, the optical characteristics of the

span band method is much better than those of the

MUCIS method.

The correcting method using the writing

start position adjusting means 1140 is called a

20   triangle prism method.

The image forming apparatus 1 to which this

embodiment is applied may include the scanning line

curve correcting means 1071, the scanning line

inclination correcting means 1072, and the writing

25   start position adjusting means 1140, so that a

correcting weak point of each means can be complemented by each other. Accordingly, it becomes possible to realize scanning position accuracy of 10 μm, improving the scanning position accuracy.

5   Specifically, in the case of the span band method using the scanning line curve correcting means 1071 and the scanning line inclination correcting means 1072, when errors in mechanism accuracy of the holding member 1061, and position accuracy of a

10   supporting point (of the roller 1093, for example) for tilting operation in the γ direction are accumulated, a displacement amount of the scanning line is scattered between the respective stations. However, this scattering of the errors can be

15   corrected by using the writing start position adjusting means 1140 in the triangle method so as to remove the position displacement. Meanwhile, according to the triangle method, the scanning position is shifted in a parallel direction, but when

20   accuracy errors of the components are accumulated, a little inclination component of the scanning line is generated. This generated inclination can be corrected by the correcting in the γ direction, using the scanning line curve correcting means 1071 in the

25   span band method.

In a case where a timing of electrically writing is adjusted to correct the scanning position, it is difficult to realize accuracy of 10 μm. However, according to this embodiment of the present

5   invention, by such a complementing method, the light scanning device 1020 includes the scanning line inclination correcting means that can correct the inclination of 700 μm, and the scanning line curve correcting means that can correct the curve of 20 to

10   30 μm, and the writing position adjusting means that can correct the position displacement of $\pm$ 50 μm. Accordingly, by the combination of the scanning line inclination correcting means, the scanning line curve correcting means, and the writing position adjusting

15   means, it is possible to perform the correcting operation that enables accuracy of 10 μm.

In the above, the light scanning device and the image forming apparatus according to the present invention is described, but it is sufficient that the

20   holding member holds at least one optical element. A target of the scanning line curve correcting means 1071 and the scanning line inclination correcting means 1072 is not limited to the second scanning lens 1030, and may be another optical element or a

25   plurality of optical elements including the second

scanning lens 1030. The pressing member may be sphere-shaped. In this case, the axial direction of the pressing member can be freely set. The image holding member such as the photoconductive body may

5 be drum-shaped or belt shaped.

According to this embodiment, the scanning line curve correcting means and the scanning line inclination correcting means may be provided in accordance with a necessity of a correcting operation,

10 and may be provided for performing correction on at least one beam of the beams corresponding to a plurality of the image holding bodies. Furthermore, when a plurality of the scanning line curve correcting means and the scanning line inclination

15 correcting means are provided, it is possible to activate at least one of the scanning line curve correcting means and the scanning line inclination correcting means. In other words, it is possible to perform the correcting operation on at least one beam

20 of the beams corresponding to a plurality of the image holding bodies.

In the above-described configuration, the leaf springs 1095 and 1096 have a curve shape, but the present invention is not limited to this shape,

25 and the leaf springs 1095 and 1096 may have a

rectangular shape. In the case of the rectangular leaf springs 1095 and 1096, it is relatively difficult to adjust the pressing force in the sub scanning direction B, but there is an advantages in that the rectangular leaf spring is strong against the applied force such as vibration in the scanning direction A and the optical axis direction orthogonal to the direction B.

The above-described configuration adopts the span band method in which both ends of the held optical element are supported by using the beam (leaf spring) structure, and the scanning line inclination is corrected by using the beam structure. However, except for the examples of FIGS. 31 and 32, instead of the both side beam structure in which both ends of the held optical element are supported by the beams (leaf springs), respectively, the one side beam structure, in which one end of the held optical element is supported by the beam (leaf spring), and the other end of the held optical element is only put on the fixed member, may be adopted. In the case of the one side beam structure, the held optical element is supported only by the friction force in the scanning direction A and the optical axis direction C orthogonal to the sub scanning direction B that is

pressing direction, so that the directions A and C are weak against vibration, and the held optical element can be moved in the pressing direction, that is, the sub scanning direction B. As a result, the

5   fine adjustment can be performed on the pressing force.

According to one aspect of the second embodiment, there is provided a light scanning device comprising:

10   an optical element that images, on an image holding body, a light beam emitted from a light source;

a holding member that holds the optical element;

15   scanning line curve correcting means for correcting the optical element in a sub scanning direction to correct a scanning line formed by the light beam in the sub scanning direction; and

scanning line inclination correcting means

20   for entirely tilting the optical element to correct an inclination of the scanning line,

wherein at least one part of the scanning line curve correcting means, and at least one part of the scanning line inclination correcting means are

25   provided integrally with the holding member. Thereby,

it is possible to effectively suppress the deformation of the optical element (particularly, the resin-made optical element) included in the scanning imaging optical system caused by the temperature

5 change. Furthermore, by this configuration, when this deformation and the warping generated by the remaining stress at the time of molding the optical element causes the scanning line curve and inclination, it is possible to correct this scanning

10 line curve and inclination. By this configuration, by intensively providing the correcting mechanism to the holding member, it is possible to easily correct the scanning line curve and inclination with the relatively low cost, improving cost reduction.

15 According to another aspect of the second embodiment, the holding member includes a reference surface that contacts with the optical element, and that provides a position reference for the optical element in the holding member,

20 and the holding member further includes a supporting member that is long in a main scanning direction, and that supports the optical element from the sub scanning direction.

Thereby, by making the optical element

25 contact against the reference surface of the

supporting member, the optical element can be positioned within the allowable accuracy in terms of the main scanning direction and the sub scanning direction with the optical element being supported. Furthermore, by this configuration, the supporting member can shut heat transmission when an environmental (ambient) temperature is raised. In this manner, it is possible to prevent partial change in refraction index of the optical element, and prevent an abnormal image such as an undesired black line caused by thickening of a light beam, forming good image.

According to another aspect of the second embodiment, the reference surface is formed at a part that does not correspond to both end parts of the optical element.

Thereby, the optical element can be supported and pressed at plural points so that the optical element can be deformed to be M-shaped or W-shaped in the main scanning direction. Therefore, the optical element can be deformed to have a shape suitable to the correcting of the scanning line curve. Accordingly, it is possible to correct the scanning line position error including error contribution from another optical element such as the reflection mirror.

According to another aspect of the second embodiment, the scanning line curve correcting means includes pressing means for pressing the optical element from an opposite side of a surface of the optical element that contacts with the supporting member.

Thereby, it is possible to correct the large warping of the optical element, and perform fine correction on the scanning line position. Therefore, the scanning line curve can be accurately corrected.

According to another aspect of the second embodiment, the reference surface is formed at a position that does not correspond to a position where the pressing means presses the optical element.

Thereby, the correcting of the optical element can be performed by small stress. Therefore, it is possible to easily and reliably correct the optical element.

According to another aspect of the second embodiment, a plurality of the pressing means are provided in a longitudinal direction of the supporting member.

Thereby, the correcting operation performed by the scanning line curve correcting means can be performed with high accuracy.

According to another aspect of the second embodiment, a single number of the pressing means is provided approximately at a center in the longitudinal direction of the supporting member.

5   Thereby, the configuration of the scanning line curve correcting means can be relatively simplified, so that the light scanning device can be made at relatively low cost.

According to another aspect of the second

10   embodiment, the pressing means comprises:

a pressing member that engages the optical element from an opposite side of a surface of the optical element that contacts with the supporting member; and

15   a pressing operation member that pushes the pressing member against the optical element.

Thereby, the pressing member can be pushed against the optical element by the pressing operation member so as to correct the large warping of the

20   optical element and perform correction of the scanning line position.

According to another aspect of the second embodiment, the pressing operation member includes a tapered pin, and when the tapered pin is moved in an

25 axial direction of the tapered pin, the tapered pin

pushes the pressing member against the optical element.

Thereby, it is possible to provide the light scanning device that can perform fine correcting of the curve of the optical element by using the relatively simple configuration.

According to another aspect of the second embodiment, the pressing member has a cylinder shape of which axial direction is approximately parallel to an optical axis direction of the optical element, and an axial direction of the tapered pin is approximately orthogonal to the axial direction of the cylinder shape.

Thereby, when the optical element is expanded or contracted by environmental temperature change, the pressing member can prevent this expansion or contraction of the optical element. In this manner, optical characteristics of the optical element are not affected by the temperature change. Therefore, it is possible to provide the light scanning device that can perform fine correction on the curve of the optical element by using the relatively simple configuration.

According to another aspect of the second embodiment, the optical element includes a depression

part that is formed at the surface of the optical element that contacts with the pressing member,

and a length of the pressing member in the axial direction of the cylinder shape is longer than a width of the depression part in the optical axis direction of the optical element.

Thereby, it is possible to stabilize the contact between the pressing member and the optical element. Therefore, it is possible to provide the light scanning device that can reliable correct the scanning line position.

According to another aspect of the second embodiment, the pressing means includes a screw that is moved relative to the optical element in a direction including the sub scanning direction.

Thereby, the configuration of the scanning line curve correcting means can be relatively simplified. Therefore, it is possible to provide the light scanning device that can correct the scanning line curve at relatively low cost.

According to another aspect of the second embodiment, the holding member comprises a sandwiching support member that is positioned at an opposite side of the surface of the optical element contacting with the supporting member, and that

sandwiches and supports the optical element in corporation with the supporting member.

Thereby, the deformation of the optical element can be prevented by sandwiching the optical element by the supporting member and the sandwiching support member. Furthermore, the warping of the optical element caused by the temperature distribution difference in the main scanning direction can be corrected by pressing the optical element at the side of the sandwiching support member. For example, it is possible to reduce the fluctuation in the scanning line curve caused by environmental change at the time of a successive printing operation.

According to another aspect of the second embodiment, at least one part of the pressing means, and at least one part of the scanning line inclination correcting means are provided integrally with the sandwiching support member.

Thereby, not only the supporting member and the sandwiching support member can support the optical element, but also the sandwiching support member can support the at least one part of the pressing means and the at least one part of the scanning line inclination correcting means. In this manner, it is possible to provide the light scanning

device that can correct the scanning line curve and inclination at the side of the sandwiching support member with the entire size of the light scanning device being reduced.

According to another aspect of the second embodiment, the scanning line inclination correcting means entirely tilts the holding member together with the optical element to correct the inclination of the scanning line.

Thereby, for example, when the reflection mirror is tilted in the γ direction for correcting the, a generated adverse effect such as the deterioration of the magnification error in the main scanning direction can be removed. Furthermore, the optical element can be tilted in the γ direction with the optical element being held by the holding member so as to correct the scanning line inclination. In this manner, the scanning line inclination can be corrected without deteriorating the magnification in the main scanning direction.

According to another aspect of the second embodiment, the scanning line inclination correcting means includes a supporting point member that provides a supporting point when the scanning line inclination correcting means tilts the holding member.

Thereby, it is possible to provide the supporting point for adjusting the scanning line inclination by using the relatively simple configuration.

5   According to another aspect of the second embodiment, the supporting point is positioned near the optical axis of the optical element.

Thereby, it is possible to suppress the optical characteristics change of the optical element when the optical element is tilted to correct the scanning line inclination.

According to another aspect of the second embodiment, independently of each other, the scanning line curve correcting means and the scanning line inclination correcting means correct the scanning line.

Thereby, the correcting of the scanning line curve, and the correcting of the scanning line inclination can be performed independently without affecting each other. Accordingly, it is possible to correct the scanning line easily with high accuracy.

According to another aspect of the second embodiment, the light scanning device is used for scanning a plurality of the image holding bodies by the light beams.

Thereby, it is possible to provide the light scanning device that can exhibit the above-described advantages when scanning a plurality of the image holding bodies.

According to another aspect of the second embodiment, the plurality of image holding bodies are provided for forming toner images of colors that are different from each other.

Thereby, not only the scanning line curve and inclination can be corrected by the relatively simple configuration at low cost, but also the scanning lines corresponding to the respective colors can be made to conform with each other even at the time of rapid temperature change (for example, successive printing) in the light scanning device. Therefore, it is possible to improve quality of a color image with the color difference being prevented.

According to another aspect of the second embodiment, the scanning line curve correcting means and the scanning line inclination correcting means correct at least one beam of the beams corresponding to the plurality of image holding bodies, respectively.

Thereby, in accordance with a necessity, it is possible to correct the scanning line curve and

inclination so that the scanning lines corresponding to the respective colors can be made to conform with each other with high accuracy.

According to another aspect of the second embodiment, one of the colors is set as a standard color,

and the scanning line curve correcting means and the scanning line inclination correcting means perform correcting to conform, with the scanning line of the standard color, the scanning lines of the light beams corresponding to the colors other than the standard color.

Thereby, it is possible to omit the correcting operation for the standard color. Further, the scanning lines corresponding to the respective colors can be made to conform with each other with high accuracy, Therefore, the scanning line curve and inclination can be corrected by using the relatively simple configuration at low cost.

According to another aspect of the second embodiment, the standard color is black or magenta.

Thereby, the color that has relatively high contrast, and that is more affected by an outside disturbing factor such as vibration and temperature change is set as the standard color, and the

correcting operation of the standard color is omitted. In this case, the scanning optical system corresponding to the standard color can be fixed, and the rigidity of this scanning optical system can be

5 made large. Therefore, it is possible to provide the light scanning device that is less affected by the outside disturbing factor, and that can contribute to forming of an image having good contrast. Particularly, when the standard color is black, it is

10 possible to maximize this advantage.

According to another aspect of the second embodiment, the light scanning device further includes:

deflecting means for deflecting the light

15 beam;

an optical path refracting member that is provided between the light source and the deflecting means; and

writing start position adjusting means for

20 changing the position of the scanning line in the sub scanning direction by rotating the optical path refracting member approximately around an optical axis of the light beam to be refracted by the optical path refracting member.

25 Thereby, even when the position of the

scanning line is displaced in the sub scanning direction due to rapid temperature change, it is possible to effectively correct the relative color difference between the respective colors, improving

5   color image quality.

According to another aspect of the second embodiment, the optical path refracting member includes a wedge-shaped prism.

Thereby, the position of the scanning line

10   can be corrected by using the compact and low-cost optical path refracting member.

According to another aspect of the second embodiment, the light scanning device further comprises position displacement detection means for

15   detecting a writing start position displacement in the sub scanning direction that is relative amount between the plurality of image holding bodies,

wherein feedback control of the writing start position adjusting means is performed based on

20   the detected writing start position displacement.

Thereby, even when the optical characteristics change is generated due to the time lapse to cause the position of the scanning line to be displaced in the sub scanning direction on the

25   image holding body, it is possible to effectively

correct relative color difference between the respective colors, forming good color image.

According to another aspect of the second embodiment, the position of the scanning line on the image holding body is controlled by using the writing start position adjusting means during writing of image data.

Thereby, it is possible to correct the relative color difference between the respective colors in almost real time.

According to another aspect of the second embodiment, the light scanning device further comprises a fixed member that supports the holding member such that the holding member is movable in a direction of correcting the inclination of the scanning line,

wherein the scanning line inclination correcting means comprises:

an elastic member that is provided integrally with the holding member and the fixed member, and that supports the holding member such that the holding member is movable relative to the fixed member in the direction of correcting the inclination of the scanning line; and

holding member tilting means for tilting the

holding member against force generated from the elastic member.

Thereby, it is possible to prevent deterioration of the optical element due to service life, for example, by the relatively simple configuration and at low cost.

According to another aspect of the second embodiment, the holding member tilting means includes a screw.

Thereby, it is possible to reliably correct the scanning line inclination by relatively simple low-cost configuration.

According to another aspect of the second embodiment, the scanning line inclination correcting means comprises:

driving means, provided integrally with the holding member, for driving the holding member to be tilted;

inclination detection means for detecting the inclination of the scanning line; and

control means for causing the driving means to entirely tilting the holding member, in accordance with the detected inclination of the scanning line, so that the inclination of the scanning line is corrected.

Thereby, the feedback control on the driving means is performed by the control means using the inclination detection means so that the scanning line inclination can be removed automatically and

5   accurately.

According to another aspect of the second embodiment, the light scanning device further comprises a fixed member that supports the holding member such that the holding member is movable in a

10   direction of correcting the inclination of the scanning line,

wherein the scanning line inclination correcting means comprises:

an elastic member that is provided

15   integrally with the holding member and the fixed member, and that supports the holding member such that the holding member is movable relative to the fixed member in the direction of correcting the inclination of the scanning line; and

20   holding member tilting means as the driving means for tilting the holding member against force generated from the elastic member.

Thereby, it is possible to prevent deterioration of the optical element due to service

25   life by the relatively simple and low-cost

configuration. Furthermore, the feedback control on the driving means can be performed by the control means using the inclination detection means so that the scanning line inclination can be corrected automatically and accurately.

According to another aspect of the second embodiment, the elastic member includes a leaf spring and/or a coil spring.

Thereby, it is possible to prevent deterioration of the optical element due to service life, reliably correcting the scanning line inclination.

According to another aspect of the second embodiment, the elastic member is a leaf spring and/or a coil spring.

This patent application is based on Japanese priority patent application No. 2002-274689, 2003-022674, and 2003-201885 filed on September 20, 2002, January 30, 2003, and July 25, 2003, respectively, the entire contents of which are hereby incorporated by reference.